THE IMPACT OF STUDENT LOCUS OF CONTROL ON ACADEMIC ACHIEVEMENT AS A FUNCTION OF LECTURE VERSUS COMPUTER-ASSISTED INSTRUCTION

By

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ABSTRACT

THE IMPACT OF STUDENT LOCUS OF CONTROL ON ACADEMIC ACHIEVEMENT AS A FUNCTION OF LECTURE VERSUS COMPUTER-ASSISTED INSTRUCTION

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The infusion of computers into the educational system raises questions regarding the appropriate use of such technology. This study, formulated in the aptitude-treatment interaction model, investigated the functional dependence of academic achievement on the personality variable of locus of control. The study contrasted computer-assisted instruction with traditional lecture.

The literary review providing background support was drawn from three areas: 1) locus of control; 2) computer-based instruction; and 3) aptitude-treatment interaction studies. The intent was to document the contribution these three areas have made in academic achievement.

The study utilized two independent variables: 1) locus of control (internal/external); and 2) instructional methodology (CAI/lecture). The Intellectual Achievement Responsibility (IAR) Questionnaire was used as the measure of locus of control serving to identify the internally and externally oriented students. The dependent measure was academic

performance on a teacher-made test covering topics in College Algebra.

Subjects were 51 students enrolled in two intact classes (32-Winter 1983, 19-Spring 1983) of College Algebra. These subjects were predominantly Black, freshmen students enrolled in the Michigan State University College of Engineering. The IAR Questionnaire was administered to a larger group of predominantly white engineering students as a means of assessing representativeness of the experimental samples.

The 2-by-2 design was analyzed using variance, covariance, and linear regression techniques. Analysis of covariance was performed using the covariates of MSU math placement score, ACT math score, formal instruction time, external study time, home work grade, quiz score, course test scores, and the previous math course grade. Analyses were performed for each trial separately and for a combined sample.

The study found no significant differences in achievement for locus of control orientations or for instructional methods. No significant interactions were found. Analysis of covariance revealed one significant main effect for instructional method when the MSU math placement score was controlled. Linear regression analysis indicated that treatment regression lines were statistically parallel with slopes equivalent to zero. Although the lecture method tended to produce higher achievement scores, the CAI method required 42% less instructional time.

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I would also like to thank two colleagues, Thad Roppel and Pam Reisner. Thad assisted in the development of several sections of the CAI software system and served as a sounding board for many of the computer applications used in this study. Pam contributed to the design of the courseware materials and acted as the classroom lecturer. Finally, I wish to recognize members of the College of Engineering and the Office of Minority Student Education who supported this project through their contribution of financial and physical resources.

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CHAPTER I

INTRODUCTION

The educational system in the United States is in the midst of a revolution. Although this revolution is quiet and benevolent it will nonetheless leave few educators and administrators untouched. Ashby (1967) has identified this revolution as the fourth to affect education. The organization of schools wherein verbal instruction, exemplified by Socratic dialogue, was the delivery mode represented the first revolution. The second and third revolutions are characterized by their use of hand written and printed materials respectively. The fourth and current revolution is distinguished by its use of electronic technology. Ashby (1967) states that:

> ...new technologies are being adopted in teaching which will certainly transform the whole process of education, though what the transformation will be is still a matter for speculation. (p. 361)

Indeed, the use of electronic media has been slowly incorporated into the educational system over the past four decades. The advent of computer technology and specifically microcomputer technology, however, has brought the revolution into a new focus and perspective.

The Carnegie Commission (1972) addressed the impact of electronics on the educational system and made recommendations that would promote and enhance the acceptance, applicability, and use of the tools of the fourth educational revolution. The authors of that report did not forsee the development of microcomputers in 1975. Since that time, inexpensive and surprisingly powerful computer systems have become obtainable for a few hundred dollars.

Educational theorists have also been developing methodologies for effective learning. The mastery learning technique advocated by Bloom (1971) and the Personalized System of Instruction approach of Keller (1968) emphasize the development of learning packets designed for individual use. The intent of both methods is to allow students to learn and master instructional materials at their own pace. These two approaches are among several that promote learning in a flexible and individualistic manner. These models address the issue of individual differences between students by restructuring the educational materials and environment to suit the learners' needs.

In addition to advancements in technology and learning theory, a third factor impacting on the educational system has been the continued research into how affective characteristics contribute to academic achievement. Most notable among these is the aptitude-treatment interaction research. This research attempts to determine the relationship between affective or behavioral variables and instructional methods, educational environment, and academic achievement. The philosophy is that there is no one best method for teaching. Indeed, the best method may be a combination of several available techniques. Again, the issue of individual differences is addressed but from a perspective that tries to match students to the appropriate instructional method on a situational basis.

The development of the microcomputer has, in some quarters, been heartily embraced as the tool for truly individualizing instruction. Computer-assisted instruction (CAI) has made significant inroads into the pre-college educational system. It is also heavily used in business and industry and the military for job training and advancement. Additionally, there is small but growing use of computers for the preparation and delivery of instruction at the collegiate level. Other educators view computers as a real threat to their jobs, authority, and freedom. The majority of teachers, however, are taking a wait and see approach. Oettinger and Marks (1969) do not consider computers as either a boon or a boondoggle. They will take their place in the educational system along with the carousel slides, movie projectors, and video tape players.

Computer systems, however, are perceived by some as a threatening and controlling influence. The "big brother" concept is readily associated with computers and the fact that computer storage systems can record seemingly everything reinforces the perception of power and control. The issue in question is how an individual's sense of personal control determines subsequent outcomes in different situations. The concept of locus of control, formally defined by

Rotter (1954), provides a means for investigating student performance in the novel environment of CAI. Do students believing their successes and/or failures are primarily due to external controlling factors have different levels of achievement than individuals who assume personal responsibility for their successes and/or failures? In what way does the locus of control factor interact with instructional methodology, particularly CAI? Locus of control does appear to be one personality variable which merits investigation relevant to its interaction with instructional methodology and the combined effect on achievement.

Identification of the Problem

The challenge facing educators is to define, shape, and guide the impending transformation of the educational system. This involves understanding the capabilities of the new computer technology and its potential use in education. It transcends simply designing computer-based instructional materials for it includes determining when, under what circumstances, and for whom the use of computers is warranted. The classroom in the year 2000 will be vastly different from what it is today. By that time the fourth educational revolution will be over. What happens now, during the revolution, will have a profound impact upon the quality of the future educational system.

Research into the means, methods, and necessity of computerizing education needs careful investigation and

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resolution. If computer usage in education is viewed on a continuum with total absence and total implemetation at the extremes, the global issue is to determine the optimal usage of the technology. To adopt a Luddite philosophy and ignore the computer and its potential use for the development, delivery, and management of instruction is impractical. This is a real possibility if the design of hardware systems is inadequate and, more importantly, if the quality of the instructional software is inferior to the more conventional printed materials. The progression is clear. Verbal instruction became enhanced with the advent of hand written materials that could be shared between individuals. The development of the Gutenberg press allowed for the mass production and widespread distribution of information. Computer technology therefore, can and should be utilized in the management of educational materials, resources and facilities, and in the actual delivery of instruction.

Embracing the opposite extreme by viewing computer technology as a panacea to current educational problems is also impractical. The educational system, described by Kozma, Belle, and Williams (1978), is an integration of instructors, students, the subject matter, and instructional delivery methods--all within the boundaries of a learning environment. Computer technology alone is not the answer to current problems in any one of these areas. If viewed as a multidimensional space, the problem becomes at once more

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complex (adding more dimensions) but also more manageable by investigating the optimal effectiveness (cost, resource utilization, learning, time reduction, etc.) of computer technology along any particular dimension.

These dimensions are not independent, however, and any two can be thought of as defining a plane in the complex educational space. As one moves off the axes that define a plane, the issue becomes one of the interaction between the two dimensions. This study will consider the dimensions of the student, the instructional delivery method, and their interaction. The plane formed by these two variables provides research opportunities for identifying the student characteristic-instructional methodology matches that enhance learning. The specific problem considered herein is to determine the extent that student locus of control can be used to predict academic achievement based on the avalability of lecture and computer-assisted instructional methodologies.

Definition of Terms

Many of the terms in this study encompass a broad range of activities as reported in the literature. Salisbury (1971) listed 21 terms synonymous to computer-assisted instruction in his attempt to standardize the terminology associated with the usage of computers in education. More recently, Burke (1982) provides an excellent glossary of the terminology used in this rapidly expanding area. The definitions listed here, however, are solely for the purpose of this study.

Artificial Intelligence (AI): A subfield of computer science concerned with the concepts and methods of symbolic inference by a computer and the symbolic representation of the knowledge to be used in making inferences. A computer can be made to behave in ways that humans recognize as "intelligent" behavior in each other (Fiegenbaum & McCorduck, 1983).

Aptitude-Treatment Interaction (ATI): An ATI occurs whenever the regression line of the outcome from one treatment, based upon some kind of information about the student's pretreatment characteristics, differs in slope from the regression line of the outcome from any other treatment (Cronbach & Snow, 1977). In this study the two treatments are lecture and computer-assisted instruction and the pretreatment characteristic is student locus of control. The intent of ATI research is to generate predictive models (regression equations) that reflect the interdependance of student characteristics and instructional methods.

Branching Program: Any program which uses built-in branching. Branching is usually designed to allow some students to bypass some of the material of the program based on their performance in the program to that point (Burke, 1982). Also known as intrinsic, Crowderian, or scrambled programs.

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<u>Computer-Assisted Instruction (CAI)</u>: Any method of learning in which a computer is the primary delivery system (Burke, 1982). The term has evolved to imply direct, on-line, interactive use of computer facilities. Also known as Computer-Assisted Learning (CAL) or Computer-Assisted Training (CAT).

<u>Computer-Based Instruction (CBI)</u>: Nearly synonymous with CAI. However, some people may reserve the term CBI for cases in which there is less direct interaction with the computer (Burke, 1982). The term often represents the genesis of all computer related activities in education. Also referred to as Computer-Based Education (CBE).

<u>Computer-Managed Instruction (CMI)</u>: CMI has come to mean the systematic control of instruction by the computer. It is characterized by testing, diagnosis, learning prescriptions, and thorough record keeping (Burke, 1982).

<u>Courseware</u>: It has become popular to refer to CAI lessons as courseware rather than software (Burke, 1982). The instructional materials specifically prepared for delivery by a computer system will be considered courseware. The particular design of the instructional system used in this study necessitates this distinction between courseware and software.

<u>Disordinal Interaction</u>: One of the possible outcomes of aptitude-treatment interaction research. An interaction is disordinal if the regression lines for the different treatments cross within the range of the aptitude variable

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(Cronbach & Snow, 1977). This type of interaction indicates that a differential application of treatments based on aptitude measure may be of benefit.

Hardware: The physical parts or components of a computer system. Hardware includes the electronic elements, chips, keyboard, video monitor or VDT, and perpherial devices such as printers, disk drives, and telephone modems (Toong & Gupta, 1982).

Interactive: A term which describes a learning process in which the student and the system alternate in addressing each other. Typically, each is capable of selecting alternative actions based on the actions of the other (Burke, 1982).

Linear Program: A program which contains little or no branching. In other words, every student who goes through the lesson sees exactly the same information and questions. The logical branching which occurs in providing feedback to either a correct response or an incorrect response does not disqualify a lesson as linear (Burke, 1982). Programs of this type are also known as extrinsic programs.

Microcomputer: A small machine that receives, stores, manipulates, and communicates information under the direction or control of a microprocessor. A microprocessor is a single integrated circuit on a square chip of silicon that is typically a quarter of an inch on a side (Toong & Gupta, 1982).

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Ordinal Interaction: One of the possible outcomes of ATI research. In an ordinal interaction one regression line remains above but not parallel to the other regression line (Cronbach & Snow, 1977). If the two regression lines are parallel to each other then there is no interaction between treatments and characteristics. This type of interaction may indicate a differential application of treatments but not based solely on the aptitude variable.

Programmed Instruction (PI): Instructional materials that use the principles of programmed instruction: 1) small steps, 2) active responding, and 3) prompt feedback (Burke, 1982).

Software: The sequence of instructions that direct the hardware components to perform a certain task is known as the software. The core of the software is an operating system that controls computer operations and manages the flow of information. Software typically refers to programs or application programs which enable the computer to perform specific tasks (Toong & Gupta, 1982). The model used in this study distinguishes software as the data processing program from courseware which is the data being processed.

Student Locus of Control (LOC): An affective variable indicating the degree to which an individual perceives that reinforcements are contingent upon his/her own behavior. Internal individuals assume responsibility for subsequent events while externally oriented subjects feel powerless and of

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often manipulated by others. A more formal definition and discussion of this concept is provided in the review of the literature.

Purpose of the Study

Research into the three basic components of this study--computer-based education, role of affective characteristics in educational achievement, and aptitude-treatment interactions--has proceeded largely in isolation. Much of the research into affective variables has focused on the identification of such variables, development of reliable assessment procedures, and correlation with other affective measures. Aptitude-treatment interaction studies have been overshadowed by correlational studies that attempt to show significant treatment effects. Of the aptitude-treatment interactional studies that have been performed very few involve computer-assisted instruction as one of the treatments. The major reason for this is that the availability of inexpensive microcomputer systems is relatively new and, therefore, still subject to the correlational or "one best method" type of research. The literature is replete with studies that compare CAI to traditional or other non traditional (PSI, PI, etc.) methods. The particular research method used in most of these studies attempts to determine which of the treatments provides for more effective learning for all students. The availabiltiy of microcomputer systems has

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has simply changed the equipment used in the research and not the research approach.

Empirical evidence on the relationship between the content and structure of computer-based instructional materials, the procedures by which computers can or will be permitted to modify those materials, and the short and long term effects on the students is required for the proper design and utilization of the new technology. Regardless of the advances made in the technological area, computer-based education is not necessarily the best method for teaching all students. Until educators can understand the relationships between computers, instructors, students, and the structure of the subject matter, and can define the conditions for effective and efficient use of the emerging computer technology, they run the risk of having the commercial entrepreneurs determine the quality of educational software and hardware. Indeed, there is a rapidly increasing market for ready to run microcomputer based instructional materials and this demand is only surpassed by the abundance of software vendors and products.

It is the emergence of microcomputer technology that is enabling state-of-the-art educators to investigate the uses of these machines for the preparation and delivery of educational materials on an individual basis. Microcomputers can indeed be directed to reconfigure units of instruction to be more attuned to the specific needs of the learner. However, questions arise as to the intended use and design of

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instructional software as well as the quality and acceptance of the methodology itself.

The foremost purpose of this study is to investigate the existence of an interaction between student locus of control and the method of delivering instruction. Additionally, analysis procedures will indicate if there is a difference between delivery modes themselves. Moreover, the study consisted of two experimental trials as a means of replication and examination of the stability and generalizability of any aptitude-treatment interaction. The two trials are identical in all respects except that different subjects were used.

Statement of Research Questions

The major emphasis of this study was to determine the extent that student locus of control predicts academic achievement based upon differences in the methods of instruction. Two distinct instructional methodologies are compared: lecture and computer-assisted instruction. The issue was not to determine which method is best but to determine whether the interaction of locus of control and instructional technique has a predictable relationship with achievement. Results of this and similar aptitude-treatment interaction studies will help decide both to what extent and in which manner computers should be used in instruction.

The independent variables for the study consist of the two instructional models, lecture versus computer-assisted in

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instruction, and a student locus of control measure divided into internal and external subgroups. The dependent variable is academic achievement on the material covered during the experiment. Four main research questions are addressed. First, to what extent is achievement effected by the method of instruction? Second, is student locus of control a viable affective characteristic for predicting achievement? Third, are there significant interactions between locus of control and instructional method? Lastly, since there are two experimental trials using different subjects, are aptitude-treatment interactions generalizable across samples?

Importance

The study is important for four reasons. First, computer-based education is neither a panacea nor a placebo for the problems confronting educators. It is important to determine how students interact with computers and what role student attributes play in the interaction. The aptitude-treatment interaction studies focus on generating regression equations for prediction purposes. The development of consistent and stable regression equations could play a key role in providing students with effective instruction geared to situation variables and their learning style, of which locus of control is one possible factor. The new technology has the capability to truly address individual differences for instructional purposes.

Secondly, the viability of locus of control as a suitable student attribute for use in predictive regression equations needs to be determined. There is an abundance of affective variables that undoubtedly impact upon academic achievement and indeed the eventual form of effective regression equations may involve several of them. The circumstances in which student locus of control is one of the components needs to be determined.

Thirdly, the design of the computer-based materials is intimately related to the overall level of achievement. The quality of the instruction and the procedures by which the computer system manipulates, restructures, and presents the material warrant attention. Computer technology itself is advancing at an ever increasing rate and as newer and better computers become available, researchers will be able to develop new educational applications. The design of computer-based instruction should not automatically embrace the latest in electronic gadgetry. It must be developed from philosophical and theoretical bases and resist the almost seductive nature of electronic capabilities.

Finally, the electronic revolution is proceeding with proponents claiming less expense, greater flexibility, opportunity for students to learn at their own pace and cognitive level, and less preparation time. It is important that potential users of the electronic hardware and software systems understand the capabilities and limitations of these sys

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systems. Educators and administrators will need information on the design and effectiveness of these systems in order to make prudent decisions regarding their adoption and utilization. Bell (1979) states that:

> ...personal computers with their low costs, easy accessibility, total dedication to the user, and person-on-the-street popularity may provide the long awaited catalyst that is needed to make some dramatic change in how computers are used in schools. (p. 70)

Computer-based educational systems will not be adopted solely for the reasons listed above. They will be accepted on the basis of their capacity to provide high quality instruction, and personal computers will indeed provide the catalyst for the prerequisite research. This study represents one step toward determining some of the ingredients necessary for the development of materials that are not only effective and efficient but also acceptable to the instructors and students.

Generalizability

This study examines important issues for both the users and developers of computer-based instructional materials. The end users of these materials are the students. Therefore, recognition that affective characteristics influence academic achievement and design of materials that incorporate these variables are issues that should be of concern to all educators. The locus of control attribute has been observed and measured on the basis of age, sex, race, and nat

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nationality. The presence of locus of control as a personality trait suggests that the findings of this study can be applied across populations.

Computer technology has at least a foothold in all educational arenas and its use is not expected to decline. The results of this study, therefore, contribute to the growing pool of knowledge necessary for the integration of computers and education. This study also presents a philosophical basis from which instructional materials for a variety of subject areas and cognitive levels can be developed. Future trends regarding computers in education demand that this type of study be conducted. Other studies investigating different affective variables, computer applications, and implementation procedures also need to be performed.

Limitations

The study is limited to the investigation of only two main treatments: lecture and computer-assisted instruction. It is also limited to the single affective variable of student locus of control. Whether there exists a significiant interaction between these variables does not preclude the existence of significant interactions between these two treatments and other affective variables such as anxiety, impulsivity-reflectivity, or introversion-extroversion. Nor does it preclude the interaction of locus of control and methodologies other than lecture and computer-assisted instruction.

The study does not focus on the design and structure of the computer-assisted instructional materials or their delivery system. Computer-based materials can be prepared in any number of ways. They can be presented to the user exactly as they were prepared and entered into the machine or they can be written to require restructuring or configuration by the computer prior to presentation. Although research into the design of computer-based educational systems is needed, this study uses the linear programming instructional format.

As previously mentioned, the study was conducted twice. The first trial consisted of college students enrolled in a College Algebra course during the Winter 1983 term. A second trial was conducted the following term with a different student sample but using the same instructional materials and methods. The purpose of the dual trials was to investigate the consistency of the experimental findings. Additionally, the study is limited to the subject of mathematics which is highly adaptive to computerization. Generalizing the results of this study to other academic subjects is cautioned.

The student sample used consisted of minority students enrolled at Michigan State University. The combined sample consisted of 51 predominantely Black freshmen students enrolled in the College of Engineering. The fact that the sample was composed of a small, narrowly defined group of students could possibly limit the generalizability of the findings.

Unfortunately, only one microcomputer station was available for the computer-assisted instructional (CAI) component of the experiment. This limited the number of students who could access the CAI materials and in some cases affected the length of time available for student usage of the system. Logistical and scheduling problems were minimized, but were not entirely eliminated.

One final point of concern regards the content and conduct of the study. The author designed and wrote the computerized delivery system as well as all of the instructional materials presented in the CAI trials. The lecturer for the mathematics control groups is one of the author's colleagues and has been teaching the subject material for the past eight years. Both have been working closely together in mathematics education and collaborated on the design and content of the CAI materials. They were not unbiased observers of the experimental events and the possibility exists that their enthusiasm for both the course and the computer system may have influenced the results.

Overview of Subsequent Chapters

The second chapter contains a comprehensive review of the literature pertinent to this study. This review is intended to provide the background information dealing with the theory, methods, trends, and experimental results of research into student locus of control, aptitude-treatment interactions, and computer-based education. Chapter III presents a formal statement of the research hypotheses, a discussion of the CAI system and courseware, and the experimental design employed. The third chapter will also present the design matrix, statistical analysis procedures, and reliability and validity concerns of the study. The fourth chapter presents the results of the study. Each of the research hypotheses is restated and translated into statistical form providing the basis on which to discuss the statistical analyses. Finally, Chapter V presents a summary of the study with a discussion of the conclusions drawn from the research. Implications for future research into the area of computer usage in education and instruction are also forwarded. An insightful reflection on what transpired during this research project is given, for it assists in understanding and deciding the direction to take in this latest educational revolution.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

A review of the literature pertinent to this study comes from three distinct areas: 1) student locus of control; 2) computer-based instruction; and 3) aptitude-treatment interaction research. The first section focuses on the definition and research into the affective variable of student locus of control. The discussion of computer-based instruction presents a review of the theoretical foundations and empirical findings from over two decades of research. For both of these areas the review begins by presenting a theoretical or historical background of the subject. The major emphasis, however, is the relationship each area has with academic achievement. The effects of ethnicity, sex, anxiety, and other mediating variables are included in the discussion as a means of defining and clarifying the impact of this study. The last area is concerned with the techniques and principles of aptitude-treatment interaction research. This selective review of the literature is intended to provide the theoretical and philosophical basis underlying the research methodology of this study.

Student Locus of Control

Theoretical Background

There is little argument that academic achievement is directly related to a student's desire or motivation to learn. With an increasing emphasis on mastery learning, independent study, self-paced instruction, and alternate teaching technologies, how students perceive their ability to control these school related activities has a strong bearing on their academic performance. Hence, the notion of personal control over one's behavior and environment, or lack of it, is applicable to education.

The degree of personal control is addresed in Heider's (1958) analysis of action in which the "results of an action is felt to depend on two sets of conditions, namely factors within the person and factors within the environment" (p. 82). The concepts of "trying", "ability", "can", "wants", "difficulty", "opportunity", and "luck" are interwoven to describe the outcome of some action. Whether one attributes the outcomes to personal or environmental factors is indicative of one's perception of the locus of control for those outcomes. This formulation further posits that "behaviors can be accounted for by relatively stable traits of personality or by factors within the environment" (p. 56).

Weiner (1979) extends Heider's theory by including the dimensions of stability and control in addition to locus of causality. In his formulation locus of causality is viewed as either internal (personal) or external (environmental).

Control, on the other hand, is a separate concept which is controllable (e.g., effort; mood) or uncontrollable (e.g., ability; task difficulty). According to this taxonomy, ability is classified as internal and stable but not under ones control while luck is considered as external, unstable, and also uncontrollable. Even though the basic theory is generalizable across most situations, the degree or relative importance of causal relationships attributed to these three dimensions are situation specific.

This three factor model is an expanded version of a two component paradigm advocated earlier by Weiner, Nierenberg, and Goldstein (1976). In this earlier formulation the locus of causality and control dimensions were considered as a single locus of control attribute. Indeed, the three factor model has been criticized for non-orthogonality of the factors. Stipek and Weisz (1981) comment that the control dimension is highly correlated to both the locus of causality and the stability dimensions. Events that are typically considered external are usually not under the control of the individual. Similarly, unstable causes such as effort or mood are likely to be under the direct control of the person while stable causes (e.g., ability) are largely uncontrollable. There appears to be an unequal weighting in this causal matrix design with most unstable events being controllable and most stable events being uncontrollable.

DeCharms (1968) in his discussion of personal causation states: "Man strives to be a causal agent, to be the primary locus of causation for, or the origin of, his behavior; he strives for personal causality" (p. 269). He describes the personal-environmental basis of causality using an Origin-Pawn metaphor:

> An Origin has a strong feeling of personal causation, a feeling that the locus for causation of effects in his environment lies within himself. The feedback that reinforces this feeling comes from changes in his environment that are attributed to personal behavior. This is the crux of the concept of personal causation and it is a powerful motivational force directing future behavior. A Pawn has a feeling that causal forces beyond his control, or personal forces residing in others, or in the physical environment, determine his behavior. This constitutes a strong feeling of powerlessness or ineffectiveness. (p. 274)

Minton (1967) in his discussion of latent power provides another link between power and locus of causality by stating that:

> ...an attitude of powerfulness or high power is consistent with an action outcome of success ascribed to the person; an attitude of powerlessness or low power is consistent with success ascribed to the environment. (p. 233)

Thibaut and Kelley (1959) also separate power into two categories which they label fate control and behavior control. Although these two types of control are presented in reference to human dyadic relationships the basic idea can be generalized to person-environment interactions.

It is the social learning theory of Rotter (1954) that provides the framework for much of the research dealing with the perception of personal control. Indeed, the concept of locus of control was generated by advances made in the development of social learning theory. Its widespread acceptance as a measureable quantity, in addition to the contributions of the aforementioned theorists, has refined the original theory (Rotter, Chance, & Phares, 1972). The concept of locus of control, however, has actually existed informally for thousands of years. The phrases "fate of the gods", "lady luck", or more recently "the devil made me do it" all refer to how people perceive the relationship between their actions and the subsequent events. Rotter (1966) provided a more formal definition of locus of control when he wrote:

> When a reinforcement is perceived by the subject as following some action of his own but not being entirely contingent upon his action, then, in our culture, it is typically preceived as a result of luck, chance, fate, as under the control of powerful others, or as unpredictable because of the great forces surrounding him. When the event is interpreted in this way by an individual, we have labeled this a belief in external control. If the person perceives that the event is contingent upon his own behavior or his own relatively permanent characteristics, we have termed this a belief in internal control. (p. 1)

Although there are subtle differences between social learning, attribution, and intrinsic motivation theories these authors ascribe to, the theme of locus of control is omnipresent. Whether it is labelled as locus of control or locus of causality, or whether it is viewed as fate versus behavior control, person versus environment control, or as Origins and Pawns, it can be interpreted as the perceived causal source for the interaction between action and reinforcement.

Early formulation of social learning theory (Rotter, 1954, 1966) promoted the concept of internal-external (I-E) locus of control (LOC) as a generalized expectancy. As such the concept spawned research efforts in numerous areas. A bibliography by Throop and MacDonald (1971) lists 339 LOC studies performed in the period of 1954 to 1969. The extent of the research is also represented by the fact that 11 different locus of control assessment instruments have been devised and implemented in a variety of settings. Joe (1971) reviews locus of control as a personality variable and subdivides the research into 12 major application areas. Lefcourt (1972) also reviews LOC research making eight general categories. These reviews and others (Lefcourt, 1966, 1976; Phares, 1973, 1976; Rotter, Chance & Phares, 1972) present research findings in the areas of antecedent variables, risk-taking behavior, societal influences, cognition, anxiety, and achievement to name a few. In general, all of the reviews lend support to the social learning theory of motivation.

The research has suffered, however, in its attempt to consistently identify locus of control as a significant determinant of behavior. Rotter (1975) critiques I-E research by stating:

> Expectancies in each situation are determined not only by specific experiences in that situation but also, to some varying extent, by experiences in other situations that the individual perceives as similar. (p. 57)

He further elaborates by stating that:

> ...the relative importance of generalized expectancy goes up as the situation is more novel or ambiguous and goes down as the individual's experience in that situation increases. (p. 57)

One should, therefore, not assume a measure of generalized expectancy to be highly predictive of academic performance, especially as the amount of formal education increases.

Possibly more important in predicting behaviors than a measure of generalized expectancy is the "value" of the reinforcement in a specific situation. The concept of reinforcement value has been explicately stressed by Perlmuter and Monty (1977) and Rotter (1975), and implicitly mentioned by Hamsher, Geller and Rotter (1968), McGhee and Crandall (1968), Minton (1967), and Mischel (1977) in their discussions of possible mediating variables influencing locus of control research.

The concept of "congruence" also plays an important role in understanding behavior. Much of the early LOC research focused on performance of internal/external individuals under skill or chance conditions. Phares (1957) conducted a study in which subjects were required to match cards of slightly varying colors. Half of the subjects were told that performance on the task was due to luck while the other half of the subjects were told that performance was a matter of skill and ability. James and Rotter (1958) studied skill and chance conditions in the extinction of reinforcements in a card guessing task. Minton (1967) in a study of schizophrenics, and Watson and Baumal (1967) in an investigation of learning nonsense syllable pairs emphasize that the performance level is dependent upon the congruence between the individuals' general expectancies and the conditions under which the task is performed. All of these studies support the hypothesis that internally oriented subjects perform better under skill conditions while external subjects do better under chance conditions.

Petzel and Gynther (1970) studied performance in solving anagrams under skill and chance conditions. Contrary to the social learning theory predictions, their results indicated that externals performed better under the skill conditions while internals solved more anagrams under the chance conditions. The seeming contradiction is partially explained by inconsistencies in defining internal and external groups. Procedural differences between researchers in defining two or three groups of subjects on the I-E Scale tend to confound even significant experimental finding.

The preceding discussion has defined locus of control and commented on some of the related concepts. The discussion has not focused on academic achievement specifically but on those factors present in any task. The concepts of reinforcement value and congruence are important and indeed have an impact in the specific area of academic performance. Based on this preliminary discussion, academic achievement is a function of specific situational variables (course, physical location, teacher, etc.), the value students have for the learning task, and whether the instructional methodology is congruent with personal characteristics.

Assessment Measures

Since locus of control research covers a multitude of student variables and achievement tasks, the instruments for measuring LOC warrants a short discussion. The review by Throop and MacDonald (1971) lists 11 different LOC measures and a more current review by Stipek and Weisz (1981) contains references to 13 instruments that have been used in academic settings.

The Internal-External Locus of Control Scale (Rotter, 1966) is the most widely used assessment tool. The scale consists of 29 agree/disagree items of which eight reflect an internal orientation, seven indicate external beliefs, and six are filler items used to mask the purpose of the questionnaire. This instrument was designed to assess the generalized expectancies toward internal or external control over subsequent reinforcements. High scores on the I-E scale indicate high levels of externality.

Two closely related scales for assessing generalized expectancies are the Children's Nowicki-Strickland Internal-External Control Scale (CNSIE) and an alternate form called the Adult Nowicki-Strickland Internal-External Control Scale (ANSIE). The CNSIE (Nowicki & Strickland, 1973) and the ANSIE (Duke & Nowicki, 1974) are both 40 yes/no item questionnaires with 17 internal, 12 external, and 11 neutral items. The difference between the forms is that the ANSIE has an upgraded vocabulary for the adult audience. Scoring is in the external direction.

A third popular measure is the Intellectual Achievement Responsibility (IAR) Questionnaire (Crandall, Katkovsky & Crandall, 1965) This instrument consists of 34 choices of attribute items. Each question has two alternatives indicative of internal or external orientations. Consequently, the IAR has two subscales; one representing acceptance of responsibility for success (I+) and one for failure (I-). The composite I score (I+ plus I-) indicates a person's acceptance for both success and failure. This measure was specifically designed for academic settings and is scored in the internal direction.

Ethnicity

According to Coleman, Campbell, Hobson, McPartland, Mood, Weinfeld, and York (1966) in their comprehensive study of racial issues in education:

> ...a pupil attitude factor, which appears to have a stronger relationship to achievement than do all the "school" factors together, is the extent to which an individual feels that he has some control over his own destiny. (p. 23)

They conclude that a large percentage of the variability in school grades is attributable to this factor. Their findings indicate specifically that "minority pupils, except Orientals, have far less conviction than whites that they can affect their own environments and futures" (p. 23). The three items used in this study constitute a general perception, agree/disagree questionnaire which is now known as the Fate Control measure. The results clearly indicate that minorities, and Blacks in particular, have an external orientation toward school. They perceive their performance, as measured by course grades and standardized tests, as under the control of others and they do not believe that they have any real power or ability to improve their performance. This control factor was the predominate variable in predicting the performance of Black students in the Coleman report. It was not a significant factor, however, in determining the performance of white students.

Alker and Wohl (1972) used urban (70% minority) and suburban (100% white) school settings to determine the extent to which LOC accounted for variability in grade point averages. Students were administered Rotter's I-E scale and a cross school comparison showed no significant differences in LOC mean scores. Locus of control was a significant factor in predicting achievement in the urban school. Although LOC was not significantly related to achievement in the suburban school, a clear relationship between internality and higher GPA's was found. Moreover, an interaction between locus of control and school setting was present in which GPA's were more dependent on externality for the urban than the suburban school. Even though race was not factored out in this study, the authors noted that equivalence of LOC means between school settings implied that their results need not be interpreted on racial grounds.

In a similar study, Lessing (1969) administered the Personal Control Scale (PCS) and a Delay of Gratification Scale to 558 eighth and eleventh grade students. The PCS was specifically used as a measure of internal/external locus of control. While the Black students had lower GPA's and IQ scores, and showed significantly less control over their lives than their white counterparts, the relationship between academic performance and locus of control was not definitive. The PCS and Delay of Gratification measures did correlate with achievement but the effect was greatly attenuated when IQ was controlled. Locus of control was not found to be a major contributor in predicting achievement. Moreover, race was accountable for only a small amount of the variance in PCS scores. The study did, however, lend support to the high performance-internality connection.

Shaw and Uhl (1971) report on the relationship between LOC and reading scores for second grade students. Locus of control was assessed by the Bialer-Cromwell Children's Locus of Control Scale which yields a measure of generalized expectancy. Black subjects had higher external scores than white subjects but only in the upper-middle socioeconomic levels. There was no racial pattern for the lower SES levels. Locus of control scores were significantly related to reading scores only in the white upper-middle SES group.

Again, no racial patterns were evident in reading scores for the other SES groups.

Karmos, Bryson, and Tracz (1982) found locus of control, as measured by the I-E Scale, to be unrelated to the college GPA's of Black and white graduates. University graduates are extremely familiar with the academic environment and therefore, a measure of generalized expectancy looses its power as a predictor. This result is not entirely unexpected in view of Rotter's comments regarding the novelty of any given situation. Despite the absence of any relationship, however, locus of control scores were more external for the Black subjects in their sample.

Using the IAR Questionnaire, Soloman, Houlihan, and Parelius (1969) analyzed school grades for 262 fourth and sixth grade students. They found no significant differences on the basis of race. Katz (1967), also using the IAR scale, concurs with the findings that race does not appear to be a factor in the IAR's predictive power of school grades.

DuCette, Wolk, and Soucar (1972) studied the interaction of nonadaptive classroom behavior and locus of control. Black and white students were administered the IAR in addition to being classified as adaptable or non-adaptable according to their ability to adjust to classroom situations. Significant main effects for race were found, with Blacks exhibiting more externality on both the I+ and I- subscales. Moreover, the existence of a three factor interaction between race, behavior classification, and locus of control indicates that race had a moderating effect on the relationship between locus of control and conformity in school settings. The study also indicates that the connection between locus of control and behavior is very complex.

In straight comparative studies between Black and white samples, Rotter (1966) reports inconsistent racial trends in I-E scores. Race by socioeconomic status interactions indicate that lower class Blacks were distinctly more external than either middle class Blacks or middle and upper class whites (Rotter, 1966; Shaw & Uhl, 1971).

Studies of Black and white inmates indicate mixed results. Black inmate scores on the I-E scale were found to range from significantly more external than their white counterparts (Lefcourt & Ladwig, 1965) to no appreciable difference (Kiehlbauch, 1968). Interpretation of these two studies, and indeed many of the studies involving race, need to be viewed in the context of the larger societal events of the time. The first study was conducted during the early stages of the civil rights movement when racial repression was just becoming a major social issue. The latter study, however, took place during the height of the militant phase of that movement. Lefcourt and Ladwig (1965) prognosticated that it was:

> ...possible that in the current Negro mass movement for civil rights, there will be greater opportunity for Negroes to witness concrete changes deriving from their social actions. (p. 380)

One problem associated with ethnicity and locus of control research lies with the interpretation of LOC scores. Rotter (1966) presents evidence for a unique, single factor interpretation of the I-E scale. Critics of the measure (Abrahamson, Schludermann, & Schludermann, 1973; Katz, 1969; Mirels, 1970) forward evidence for two distinct subscales within the measure. One factor is identified with personal control and the second, which contains all of the items worded in the third person, constitutes a political/social factor.

Gurin, Gurin, Lao, and Beattie (1969) provide evidence which taints much of the race-locus of control research in which LOC is measured by the I-E Scale. A 39 item questionnaire (23 from Rotter's I-E Scale, 3 from the Personal Efficacy Scale, and 13 items that were specifically written to elicit racial beliefs) was administered to 1,695 subjects. Factor analysis of the responses identified the four subscales of: 1) Control Ideology, 2) Personal Control, 3) System Modifiability, and 4) Race Ideology. Further factor analysis of the System Modifiability and Race Ideology components produced four more factors labeled: 1) Individual-Collective Action, 2) Discrimination Modifiability, 3) Individual-System Blame, and 4) Racial Militancy. The I-E items were concentrated in the two subsections of Control Ideology and Personal Control factors lending support for a two factor interpretation of the measure.

Lao (1970) further fueled the controversy of interpreting Black responses to the I-E measure. She surveyed 1,493 Black male college students and reproduced the Control Ideology and Personal Control subscale separation on the I-E scale. Indeed, the correlation between these two subscales indicated clear support for their independence. Rotter (1975) attributes the emergence of these factors as either temporal or population artifacts which he views as possibly helpful features "if it can be demonstrated that reliable and logical predictions can be made from the subscales to specific behaviors..." (p. 63).

In summarizing the findings between locus of control and ethnic status two trends emerge. In simply comparing Black versus white locus of control scores, Black subjects tend to be more external in their beliefs. This trend appears to be largely independent of assessment measure or situational factors. However, on occasion, racial differences as measured by instruments of generalized expectancies are susceptible to both temporal and social issues. Racial differences seem to be eliminated, however, if the IAR Questionnaire is used in academic settings. The second trend is for locus of control to be moderately related to achievement measures with higher performance levels corresponding to higher levels of internality. This trend appears to be race independent.

The concerns raised by Abrahamson et al. (1973), Gurin et al. (1969), Katz (1969), Lao (1970), and Mirels (1970) highlight the difficulty in using a generalized expectancy measure to predict outcomes in specific situations. This type of incompatability may, in part, be responsible for the diverse and often confusing results from interpreting LOC scores and their impact on other measures with reference to ethnicity.

Sex

Interpreting locus of control scores on the basis of sex is no more clear than ethnicity. Studies that employ the I-E Scale indicate that female subjects are slightly more externally oriented than male subjects (Cellini & Kantorowski, 1982; Rotter, 1966; Strassberg, 1973). Data generated by the IAR Questionnaire indicates, however, that females are more internal than males for all grade levels on the I total and the I+ scales and for the I- scale in grades six through 12. The I- scores for males in grades three to five tend to be more internal than female scores although the difference did not reach significance (Crandall et al., 1965). Results obtained using the Bialer Locus of Control Scale also indicate that females were significantly more internal than males in grades six, seven, and eight (Prawat, 1976). Fendrick-Salowey, Buchanan, and Drew (1982), however, report no sex differences in the fifth or sixth grades. This sample was very small and results that are non-significant are not surprising. Prawat, Grissom, and Parish (1979), using the CNSIE measure, reported that females are more internally oriented than males in all grades (3-12) with the lone exception of grade nine.

Studies investigating locus of control and school achievement are dependent on both the achievement tests and the locus of control measures. Barnett and Kaiser (1978), using the IAR Questionnaire, found significant relationships between the I total score and IQ, school GPA, and a battery of achievement test scores for males only. Buck and Austrin (1971) found significant correlations for both males and females when the Iowa Test of Basic Skills was the Achievement measure. Brown and Strickland (1972) found internal scores on the I-E Scale to be related to college grades and frequency of extracurricular campus activities for males only.

Male I total scores were significantly and positively correlated to the reading and arithmetic sections of the California Achievement Test in grades one through three (Crandall, Katovsky, & Preston, 1962). Negative, though non-significant, correlations for the female subjects were measured in this study. Crandall et al. (1965) and McGhee and Crandall (1968) report positive and significant correlations for the I total score in relation to scores on the Iowa Test of Basic Skills and school GPA's in grades three to five. The I+ scale was a better predictor for third and fourth grade female students while the I- was a stronger indicant of achievement for fifth grade males. For grades six through 12 the California Achievement Test scores showed no consistant relationship to the IAR scores.

Messer (1972) reported that fourth grade GPA's and Stanford Achievement Test scores were best predicted by the I+ for male subjects and by the I- for females. I total scores predicted school grades better than they predicted standardized test scores for both sexes.

Clifford and Cleary (1972), promoting their Academic Achievement Accountability (AAA) measure of LOC, found significant correlations with vocabulary achievement tests for both males and females and spelling achievement for males only. Math achievement scores were not correlated to AAA scores for either sex. Overall, achievement scores were better predicted by the AAA for male subjects. Nowicki and Strickland (1973), using the CNSIE and an unspecified achievement measure report better predictability for male subjects than for females in grades three through 12. DeCharms and Carpenter (1968), however, found non-significant relationships between spelling and math test scores with the Bialer-Cromwell LOC measure for male subjects. They did find significant effects for the female subjects in their sample.

Duke and Nowicki (1974) support studies indicating that the I-E Scale does not correlate with college achievement measures (Hjelle, 1970; Rotter, 1966). Their investigation did find that ANSIE scores were correlated with college GPA's. In support of many studies, male internality was associated with higher college GPA's. However, in contrast to other studies (McGhee & Crandall, 1968; Nowicki & Segal, 1974; Prawat, 1976; Prawat et al., 1979) a significant correlation between female externality and higher GPA was measured.

In recapping the literature on sex differences in locus of control and the impact on academic achievement, three trends emerge. Contrary to the conclusions of some researchers, notably Lefcourt and Nowicki, there appears to be no consistent pattern establishing internality as a stronger predictor of academic achievement for males than for females. This hypothesis receives support only if the CNSIE scale or its variants are used. Critics point to a social desirability factor within the scale which may elicit the sexual differentiation. As a mediating variable, social desirability may influence female subjects to respond to the LOC items according to their perceptions of the appropriate response rather than with their true feelings.

There is almost uniform agreement, however, that internality is related to higher levels of achievement for both sexes. Studies that fail to find any relationship, especially those using the I-E Scale, propose that "defensive externals" sufficiently externalize LOC scores to obfuscate any correlations between internality and academic achievement. Defensive externals are described as "people who have arrived at an external view as a defense against failure but who were originally highly competitive" (Rotter, 1966, p.

21). The effects of defensive externals enter as a viable explanation for non-significant results in studies at the high school and most definitely the college levels. College students are usually highly competitive, goal oriented individuals who may indicate external orientations as a means of shifting responsibility for their failures from themselves to other external forces. Therefore, studies that fail to find significant relations between LOC and achievement, particularly at the college level, may have a sufficient number of defensive externals in the sample to reduce the correlations between LOC and achievement to a point of non-significance.

Lastly, local school grades and GPA's are more closely related to LOC scores than standardized examinations such as the Iowa Test of Basic Skills, the California Achievement Test, or the Stanford Achievement Test. The strength of the relationship, of course, depends on the LOC measure used, with the IAR being the best (Kennelly & Kinley, 1975; Stipek & Weisz, 1981). This is due, in part, to the fact that the IAR Questionnaire elicits responses within a specific context while other LOC measures tend to be more generalized.

<u>Anxiety</u>

Rotter (1975) stressed the differences between generalized and situational expectancies. As the situation becomes more familiar, the strength of a situation dependent expectancy shows mediation. The distinction between generalized and situational expectancies parallels, in many respects, trait and state anxiety (Spielberger, 1966, 1972). Spielberger (1966) contrasted these anxieties with:

> ...anxiety states (A-states) are characterized by subjective, consciously perceived feelings of apprehension and tension, accompanied by or associated with activation or arousal of the autonomic nervous system. Anxiety as a personality trait (A-trait) would seem to imply a motive or acquired behavioral disposition that predisposes an individual to perceive a wide range of objectively nondangerous circumstances as threatening, and to respond to these with A-state reactions disproportionate in intensity to the magnitude of the objective danger (pp. 16-17).

One might, therefore, be tempted to assume relationships between generalized expectancy and trait anxiety and between situational expectancy and state anxiety. Indeed, in a review by Archer (1979), 18 of 21 studies reported significant interactions between trait anxiety and locus of control. Empirical findings overwhemingly indicate that greater externality is related to higher levels of trait anxiety. The studies, typically using the I-E Scale, strongly correlate LOC scores with almost all of the popular trait anxiety measures.

Research into the relationship between LOC and specific kinds of state/trait anxiety becomes cloudy due to the diversity of the research settings. Archer (1979) lists 13 studies involving college students where measures of test anxiety (considered a measure of trait anxiety) were correlated with locus of control scores. Significant relationships between higher test anxiety and externality were reported in seven of the studies. State anxiety measures

are even more suspect for interpretation than LOC measures. Of eight studies listed that involved college students, only three reached significance. The lack of any conclusive relationship between LOC and anxiety measures, particularly state anxiety, may be attributable to the incongruity of generalized LOC expectancy, as measured by the I-E Scale, and the situation specific nature of anxiety. The strong situational expectancies tend to mask or dilute any effects that a generalized expectancy might have.

Crandall et al. (1962) report significant correlations between IAR scores and academic achievement measures (time and intensity in academic free play, IQ, and reading and arithmetic tests). Their research also concluded that the more typical achievement related correlates such as the need for achievement (McClelland, Atkinson, Clark & Lowell, 1953) and manifest anxiety (Sarason, Davidson, Lighthall, Waite & Ruebush, 1960) bore no relation to their achievement variables.

Katz (1967) studied school achievement of Black youth and the influence of test anxiety. Scores on the Test Anxiety Scale for Children showed significant differences for high versus low achievers with highly anxious subjects being poorer performers. This relationship is strongest for male subjects, leading to the conclusion that anxiety was an extremely important factor in understanding behavior, especially for low-achieving males. Although correlational

analysis was not presented, higher anxiety levels were associated with externality.

Strassberg (1973) also measured significant relationships between locus of control and anxiety with extreme externality associated with higher levels of anxiety. Morris and Carden (1981) corroborate with findings that relate externality to trait anxiety (neuroticism). Their study also indicated that LOC was the best predictor of academic achievement and that anxiety measures were uncorrelated with grades. Watson (1967) and Feather (1967) support the connection between LOC and anxiety by reporting positive correlations of externality on the I-E Scale for both manifest and debilitating anxiety. Both of these authors also found that facilitating anxiety was not related to I-E scores. They did report, however, negative correlation coefficients thereby indicating a tentative mapping of internality to facilitative anxiety and externality to debilitative anxiety. Using a modified form of the I-E Scale, Powell and Vega (1972) also correlate locus of control and anxiety in a sample of teachers and teacher aides.

The connection between anxiety and locus of control, while consistent, appears to be an enigma. Certain forms of anxiety stongly correlate with locus of control and there is a general trend for highly anxious people to be more external. However, whereas locus appears to be a fairly good predictor of academic achievement, anxiety seems to be unrelated (Crandall et al., 1962; Morris & Carden, 1981). The

causal relationship between locus of control and anxiety has been questioned by several authors (Feather, 1967; Joe, 1971; Watson, 1967). Joe (1971) ponders:

> ...whether the belief in external control is a reaction (defense) against anxiety learned on the basis of past experiences in stressful situations or whether anxiety is a reaction to the perception that the world is unpredictable, predetermined, or controlled by powerful others. (p. 626)

The relationship between these two characteristics appears to be very complex indeed.

Summary

Locus of control has been recognized as an important motivating factor in school achievement. It has been researched in a wide variety of settings using an assortment of measuring devices for the last thirty years. As a result of the diversity of the research studies, clear consistent findings are scarce. There are a few important trends in the literature, however, which are pertinent to this study.

In academic settings the IAR Questionnaire tends to be consistently superior at predicting measures of academic performance than other LOC instruments. Predictions are better for school grades than for standardized test scores. Locus of control scores tend to become more internal as a function of age and, therefore, lose their predictive power. The IAR, however, remains a strong predictor of achievement because of its situation specific design.

Whereas other measures of LOC, notably the I-E Scale, are susceptable to differences in race, SES, IQ, need for achievement, sex, and even history, the situation specific nature of the IAR coupled with its dual subscale format tends to reduce the impact of these confounding variables.

The research on anxiety and locus of control indicates a strong relationship between trait anxiety and an external generalized expectancy. State anxiety research is not consistently correlated with LOC measures, possibly due to the specific versus general incongruency of the measuring devices. Indeed, several studies have indicated that while LOC may predict achievement, anxiety measures do not (Crandall et al., 1962; Morris & Carden, 1981).

There is abundant evidence, though not entirely in agreement, to indicate that the design of the IAR Questionnaire does differentiate subjects on the basis of Rotter's (1966) definition of locus of control. The situation specific nature of the IAR also mediates possible confounding variables such as race, sex, and anxiety. Therefore, in disagreement with the Stipek and Weisz (1981) statement that situation specific measures of LOC are no better nor worse than generalized measures at predicting academic achievement, this author concludes that the IAR Questionnaire is a superior instrument for use in academic settings. This author is in agreement, however, with their conclusion that there is little support for LOC as a stronger predictor of male academic performance than for females.

Computer-Based Instruction

Historical Overview

Computers, as electromechanical devices, are a relatively recent invention having been developed during the second world war. Despite their recency, most experts in the field of computer technology would agree that by 1990 so called fifth generation computers will be commonplace (Avoli, 1981; Fiegenbaum & McCorduck, 1983). The characteristics of these generations and their approximate time frames are:

1.	Vacuum Tube Machines	1945-1960
2.	Transistor Based Machines	1960's
3.	Integrated Circuitry and Large Scale Integrated Chip Structure	1970's
4.	Very Large Scale Integrated Chip Structures	1980's
5.	Artificial Intelligence and Pseudo-human Machines	1990's

It is interesting to note that the first four generations are differentiated primarily by hardware capabilities while the fifth generation is distinguished by advances in both hardware and software. Hardware changes consist of the proposed use of cryogenics, fiber optics, bubble memory, and microcode. Software innovations include specifically designed programming languages, knowledge systems, heuristic logic, and programs that learn from their mistakes. As state-of-the-art as these terms may sound, current computer technology has been compared to the automotive industry in that "...the computers that most of us are familiar with right now, they aren't horseless carriages. They're no more than bicycles" (Fiegenbaum & McCorduck, 1983, p. 11). As advanced computer systems are used to design more efficient computers, the speed at which computer technology and computer applications evolve will far outpace the evolution of the automobile.

Computers, however, are extremely versatile machines and are now practically ingrained one way or another into our daily lives. The use of machinery for educational purposes has four distinct phases (Gable & Page, 1980).

1. Linear Systems
2. Intrinsic Branching Systems
3. Adaptive or Extrinsic Systems
4. Generative Systems

The first phase is characterized by the strictly mechanical teaching machines of Pressey (1926) and Skinner (1958). Initially developed for use as testing or evaluation systems, these machines were also useful in presenting course material. The instruction was presented in a linear sequence of "frames." Each student moved through the same sequence of frames regardless of ability or performance, hence the linear system denotation. It should be pointed out that in some respects these early machines actually imposed restrictions upon the learner; one could at least quickly scan through sections of a textbook.

The second phase is characterized by the "scrambled textbook" approach of Crowder (1959, 1962). Early devices were electromechanical machines with 35-mm filmstrips presenting instructional frames requiring the student to press one of several buttons. Each button engaged a different sequence of instructional material. The machine automatically branched to whatever sequence was engaged. Moreover, each sequence had to be carefully prepared and organized by the curriculum developer.

Some of the more advanced systems included machine control features. Internal film control codes provided for such features as engaging all user buttons, returning to the preceeding frame only, entering a correctional sequence only, and permitting backward film motion only. These internal control codes, in effect, overrode the user response and their use was predetermined by the curriculum developer. Much of the computer-assisted instruction currently available is responsive to student input but the level of branching ranges from non-existent to highly sophisticated. A majority of the systems, even though computer-based, are still considered to be of the linear model.

Adaptive or extrinsic systems are similar to Crowder's intrinsic model except that the branching techniques are based on student response histories. Computer-managed instructional systems which employ databases to record and analyze individual student responses and learner characteristics can, through Bayesian statistics for example, adapt instructional sequences to the individual learner. These systems in essence formulate a model of each student which is electronically stored between instructional sessions.

The last phase is currently under development and represents the state-of-the-art in computer applications in education. Generative systems utilize complex artificial intelligence principles to actually construct problems and answers for presentation to the student. These systems usually incorporate relational databases or semantic networks of the subject material. Semantic networks are software structures where relationships between various data items are explicitly stored as part of the instructional system. Using heuristic search and sorting techniques these programs can generate new questions or even respond to questions posed by the student (Gallagher, 1981; Mitchell, 1981).

The SCHOLAR program (Carbonell, 1970) was an early prototype of the knowledge based systems. This program, teaching South American geography, permitted both the computer and the student to ask and answer questions. This two-way interaction constitutes a mixed-initiative system. The very fact that computers are becoming capable of formulating, asking, and answering questions is a marked departure from the previous phases where subject content, sequence, and branching aspects were predetermined and explicitly programmed into the system. In a sense, these generative systems "understand" the subject material.

Carbonell's programming strategy also marks a departure from the traditional CAI instructional format. Typical CAI can be described as ad hoc-frame-oriented (AFO) in which instructional material consists of specific frames of text material, questions, answers, and diagrams. These frames have to be prepared in advance by the curriculum developer. The generative systems are considered as information-structure-oriented (ISO) CAI. These ISO-CAI systems utilize an information network of facts, concepts, and decision-making capabilities. Since these systems are not designed according to the AFO-CAI format, they are able to generate text, pose questions, and respond with the appropriate answers. Coupled with a structural parser for analyzing user input, these systems can even respond to questions input in natural language.

Koffman and Blount (1975) and Koffman and Perry (1976) incorporate models of the student in their generative systems. These models enable the systems to tailor the difficulty level of the instruction to the level of the learner. As the student becomes more proficient with the material, the computer automatically adjusts the model parameters to reflect the increased ability.

The preceding discussion indicates that through the use of artificial intelligence techniques, relational databases, and student modeling methods, computers may eventually serve as personal tutors. The progression from the very early linear models to the generative systems currently under development represents a natural incorporation of technology into the instructional process. Education may be coming full circle with the rejuvination of the Socratic dialogue--a computerized Socrates to be sure.

Historically, there have also been two predominant philosophies regarding CAI implementation--learner versus machine control (Roblyer, 1981; Splittgerber, 1979). The early mechanical systems and the more recent computer-based Stanford/CCC model are representative of the machine control paradigm (Lysiak, Wallace, & Evans, 1976). The Stanford/CCC system consists of almost total machine controlled drill and practice exercises. The use of feedback, graphics, and animation is limited in these materials. Consequently, the system and the courseware are relatively simple from both developmental and operational aspects.

Learner controlled systems are exemplified by the PLATO (Progammed Logic for Automatic Teaching Operations) system and the TICCIT (Time-shared, Interactive, Computer-Controlled Information Television) project. Both of these systems utilize programmed instructional techniques for courseware development. Bunderson (1974) defines learner-controlled courseware as having 1) a heirarchial level of student-machine discourse; 2) a modularized structure replete with relationships to instructional taxonomies; and

3) an interface between instructional system components and the learner. The TICCIT project (Faust, 1974) provided for user control over the selection and sequencing of instructional courseware. The computer-controlled and television aspects simply represent the particular hardware delivery modes.

PLATO system (Alpert & Bitzer, 1970) courseware likewise permits the student to choose the instructional materials via menu selections. Prompt feedback, help tables, forward and backward motion, graphics and animation are standard features of PLATO courseware. Although the student can select the topics to be studied, the actual instruction has been prepared in advance and tends to be rigid. Learner control aspects relative to PLATO and TICCIT simply refer to the sequencing of materials and to the amount of drill and practice desired.

The diametric philosophies represented by these CAI systems are not related to their effectiveness as instructional tools. Their applications are as distinct as their underlying approaches. The PLATO and TICCIT systems have been used at all levels of education and training while the Stanford/CCC model works well in those areas where mastery of basic facts and principles is required. These philosophical approaches have spawned research into the optimization of man-machine control and its effects on student performance which will be discussed in a later section. The generative CAI models and the systems forthcoming in the next decade will possess a blend of man and machine control. Intelligent systems, through self-regulation, will be able to either impose or to relax machine control on the basis of student performance.

Hardware Considerations

As with any new invention or application of technology, research into the effects of the physical devices and their operation on the intended users is of great importance. The computer systems now being employed in education are no exception and this section is intended to illuminate some of the hardware aspects involved. The ergonometric considerations have received much attention regarding the use of microcomputers and particularly video display terminals (VDT's) in the work place. These man-machine interactions are also pertinent to the student learner.

There are other concerns regarding equipment usage relative to the educational process. Bevan (1981), for example, investigated the relationship between performance in a learning task and the speed of presenting textual information on a video display unit (VDU). Lesson completion times, error rates, recall, and attitudes toward computerized instruction were analyzed. The empirical results were that a presentation speed of between 10 and 15 characters per second jointly optimized the four factors studied. A 480 character per second presentation speed, i.e. full screen display, detracted from the overall efficiency by increasing the reading error rates. The process of filling the VDU screen appeared to introduce extraneous factors adversely affecting the results.

Bork (1981) and Jenkin (1981) comment that newer hardware technology is not only creating problems but also expanding capabilities in the preparation and presentation of instructional materials. The use of color screens, animation and graphics, white space, speech synthesis devices, and character intensity control must now be considered by curriculum developers. The inclusion of these emerging hardware capabilities in instructional materials has generated research into the issues of screen design, screen management, and visual aesthetics.

Moore and Nawrocki (1978) investigated the use of high resolution graphics in Army training procedures. Proponents of graphics tout perceived efficiency, realism, increased student performance, accommodation of student preferences, and the provision of a system with a little panache. None of the popular reasons for including high resolution graphics were supported empirically. Research into the effectiveness of varying grades of graphics; boxed alphanumeric labeling and schematics, simple line drawings, and line drawings with animation, resulted in no statistical difference in academic performance or unit completion times (Moore, Nowrocki, & Simutis, 1979). Despite the fact that high resolution color graphics are immensely popular, these researchers found that simplicity was best. Color and realistic simulations failed to improve performance and even though subjects expressed personal preferences, there was little relationship to their performance or motivation. The overall conclusion was that the use of graphics does not, by itself, guarantee inprovement in either completion time or achievement.

Many of the newer sophisticated computer systems support foreground/background color features. Ohlsson, Nilsson, and Ronnberg (1981) investigated the interaction of text/background color combinations as they affected the speed and accuracy in scanning a matrix of letters for a specified character. Although no simple color combination was the best, several schemes were better than others in optimizing speed. The results supported the contention that the greater the difference in color wavelengths between text and background, the higher the ratings on contrast, spacing, and overall readability of the displayed material. Two optimal color combinations were forwarded for reducing the error rates in reading; green lettering on a white background or magenta on green. Oddly enough, the reverse pairing of white letters on a green background produced one of the highest error rates. The study did not investigate the joint optimization of reading speed and accuracy nor did it report on the effects of prolonged use of the VDU on eye fatigue and/or strain.

Thomas (1979) studied whether multiple-choice items were better keyed with a letter or a numerical response relative to computer keyboard input. Problems were presented to the students along with the answer that was to be input. In one study an interaction effect occurred in which typists were quicker with the letter input while non-typists were more adept at using the numerical input. Fewer errors, however, occurred when letter input was required. The errors made by non-typist subjects included pressing the space bar, the return key, or a key adjacent to the correct answer key. Although these results may have more relevance to courseware development, the design, layout, and usage of computer keyboards may be a factor. This particular study also highlights the existence of interaction effects between the hardware and the user.

This rather brief section only scratches the surface of the research into man-machine interactions. Computer hardware systems and their capabilities, especially the use of color, graphics and animation, and the variable intensity features of video monitors, have become a boondoggle for curriculum developers. These diverse capabilities, however, represent a boon for research into determining which features are effective in an instructional setting.

Software Capabilities

The power behind computer systems is the design and structure of the software programming. It is the computer programs that inform the hardware system to display information on the video monitor, to wait for user input, to retrieve or transfer information to any number of peripherals. Much of the CAI research, therefore, has been on the efficacy of different software features.

Magidson (1978) comments on the diversity of computer usage in education and the various techniques used in the preparation of CAI materials. Instructional materials are most often written using drill and practice, tutorial, or simulation paradigms. Although roughly 80% of CAI courseware is in the subject areas of mathematics, science, and the study of computers, CAI is making inroads into virtually every discipline at every educational level.

Rushby (1979) provides a slightly different but parallel classification of CAI courseware. The British equivalent of CAI is computer-assisted learning (CAL) which is subdivided into four general paradigms: instructional, revelatory, conjectural, and emancipatory. The emphasis of the instructional CAL model is on the subject material and the student's mastery of it. This model is similar to the drill and practice and the tutorial formats.

The revelatory design supports a guided learning, discovery type of process. The subject material and the basic theory are slowly revealed to the student in such a manner that the student can formulate or deduce the essence of the instruction. This model is analogous to the simulation approach mentioned earlier.

The conjectural model allows the student to formulate and test hypotheses he or she might be researching. The focus of this model is to promote student experimentation and verification or rejection of ideas or theories related to secific topics. The level of this type of CAL software is generally postsecondary because it requires a substantial knowledge base as well as abstract reasoning abilities (Dwyer, 1974; Dwyer & Critchfield, 1981).

Emancipatory CAI simply refers to using the computer as a means of reducing the student's workload. Software programs that perform data analysis and numerical calculations, word processing systems, and electronic scratch pads or spreadsheets are examples of the emancipatory usage of computers.

Burke (1982) provides a more comprehensive classification by distinguishing between the functional, physical, and logical designs of CAI materials. Functional designs consist of the drill and practice, tutorial, gamelike (simulation), and problem solving methods. The problem solving design employs the computer as an intelligent calculator and monitors the student's actions often providing guidance and redirection. This type of CAI model is similar to the conjectural paradigm previously discussed. Examples of the probelm solving CAI design are the BLOCKS (Gallagher, 1981), GIANT (Wexler, 1970), MALT (Koffman & Blount, 1975), SCHOLAR (Carbonell, 1970), and SOPHIE (Brown & Burton, 1974) programs.

The second design variable pertains to how the instructional material is to be presented (and consequently prepared) with particular emphasis on computer usage. The six basic physical designs are: 1) linear, 2) spiral, 3) branching, 4) multitrack, 5) regenerative, and 6) adaptive. The linear and branching models are the most common and have already been described. The spiral design is akin to Bruner's (1966, 1977) spiral curriculum. Each time through the material a different property of the subject is brought into focus and highlighted. The multitrack design is aligned with Gagne's (1975, 1977) learning hierarchy whereby the lowest level material may concentrate on basic facts while the highest level may be written more abstractly requiring analysis and/or synthesis of the subject matter.

The regenerative design utilizes the computer's ability to generate different numerical values, key textual phrases, or even entirely different problem sets for each student or for each time the unit is presented to the same student. Lessons written according to this design appear to be different each time they are viewed. This type of model does not "know" who is using the system; it simply generates new values or phrases each time the program is requested.

CAI lessons prepared in the adaptive model, however, utilize information about the student and can tailor the instruction to that particular individual's needs or history. These systems are still very rare and are comparable to the adaptive or extrinsic systems espoused by

Gable and Page (1980). None of the physical models discussed by Burke are as sophisticated as the generative, artificial intelligent systems discussed earlier.

Logical designs address the manner in which the instruction is presented from a cognitive psychological viewpoint. The five prominent logical designs are: 1) didactic, 2) discovery, 3) EGRUL, 4) RULEG, and 5) fading. The didactic model is typically used because it provides a convenient method for assessing student understanding. It also fulfills the perceived need for interactive dialogue between man and machine. Even though the level of dialogue is restrictive, the didactic method is one that actively engages the learner.

The discovery design involves artificially creating conditions in which the student can discover relationships and develop an intuitive understanding of the intended subject matter. Papert (1980) is a strong advocate of the LOGO language and the use of video and mechanical "Turtles" to promote discovery learning. The EGRUL model presents a series of examples designed to facilitate in the development of a rule that connects all of the examples. Both the discovery and the EGRUL paradigms rely on an inductive thought process.

The RULEG method, in contrast, is a deductive process. Students are first taught a specific rule and are typically required to apply the rule in distinguishing examples from nonexamples. In essence, it is the reverse of the EGRUL model.

The fading design is one which initially contains strong, forceful prompts to direct the learner. As the lesson proceeds, however, the prompts become weaker, eventually disappearing by the end of the unit. This particular design is useful for materials requiring memorization.

Vinsonhaler and Bass (1972) reviewed ten major drill and practice CAI studies. The studies were selected because evaluation involved standardized tests and the studies compared CAI supplementing traditional lecture to traditional lecture alone. All of three language arts studies indicated positive gains in grade-year equivalents for the CAI supplementation model of instruction. Similar results were noted for a majority of the mathematics studies. Most of the studies showed statistically significant differences favoring CAI augmentation of traditional instruction over traditional instruction alone.

A comparison of various logical designs has been investigated by Lahey (1979, 1981). He reports on the effectiveness of different instructional sequences on academic performance in electronics laboratories. The three instructional activities of examples, rule statement, and practice were combined to form four experimental sequences; rule-example-practice (RULEG); example-rule-practice (EGRUL); practice-example-rule; and a randomized sequence. Four experimental groups completed 23 CAI lessons on the PLATO system. As might be expected, the group receiving the randomized sequence required more time to complete the assignments and answered more questions. However, there wasn't any statistically significant difference in the overall performance of the four groups. There was an interesting trend that the randomized method may be advantageous in the joint optimization of time and performance.

Park and Tennyson (1980) contrasted two designs within the RULEG paradigm in the presentation of six concepts drawn from the field of psychology. The order in which examples of the various concepts were presented was either response-sensitive (dependent on student input) or response-insensitive (randomized). The six psychology concepts were defined and discussed prior to the students task of matching examples to the appropriate concept. If a student's classification of the example was correct another example of any of the concepts was presented. If the classification was incorrect, an example of the incorrectly chosen concept was immediately displayed in the response-sensitive mode, the hypothesis being one of providing a contrast of the concepts to facilitate in the removal of any over or undergeneralizations. In the response-insensitive mode the computer simply ignored the student input and presented another example at random. The results indicated that the response-sensitive mode of operation was superior with respect to achievement, reduction of instructional time, and the number of examples needed. The fine tuning capabilities afforded by computer technology are evident in this type of learning situation.

It is not uncommon for combinations of the various functional, physical, or logical designs to appear at different points within any CAI lesson. The lesson content, its proposed use, and the level of the students for whom the material is intended are three crucial factors in deciding the appropriate functional, physical, and logical designs of the CAI courseware. There are, of course, hardware capabilities that have to be considered when selecting or preparing courseware. Not all computer systems are equipped to process some of the more complex or sophisticated materials. The sequencing of materials, use of perpherial devices, and the incorporation of adjunctive media are also important factors in CAI courseware design and implementation.

Diversities of implementation strategies are almost as numerous as the individual researchers. Today computers influence practically every aspect of education. They are being used to teach a wide variety of subjects and are even assisting in the development and preparation of instructional materials. Westrom (1983) discusses the advantages and the disadvantages associated with CAI (and CMI) development and implementation as they relate specifically to the functional designs mentioned earlier. Gleason (1981) also gives an overview of microcomputer uses in education from the viewpoints of hardware, software, computer literacy programs, and research efforts. The infusion of computers into the educational system has brought a number of articles, position papers, and books speculating on their potential for both good and bad education (Chambers & Sprecher, 1980; Ellis, 1974; Hofmeister, 1982; Holmes, 1982; Leiblum, 1982). The Carnegie Commission on Higher Education (1972), Hunter, Kastner, Rubin, and Seidel (1975), Levien (1972), and Rushby (1981) provide excellent background materials on computer based instruction.

Comparative Studies

Considerable research has been conducted that compares CAI to other instructional methodologies. Avner, Moore, and Smith (1980) contrasted active and passive CAI techniques in chemistry laboratory preparation classes. The passive CAI units were essentially electronic page turners and were considered analogous to the programmed or self-paced modes of instruction. The difference between these models was that the active model required students to respond to questions and thereby demonstrate their understanding of the material while the passive units had no such questioning. Two instructional units of each type were administered to 700 college undergraduate students. One unit was of the follow-the-instructions mode while the other required the students to make decisions. Experimental results indicated that fewer errors were made in actual laboratory exercises by those students receiving the active CAI materials. This finding was restricted to the decision-making task only. No significant differences were associated with the follow-the-instructions exercise. Although the students having the interactive training took less time in the laboratory, they took more time working through the CAI materials.

In a study of nursing education Boettcher, Alderson, and Saccucci (1981) compared the CAI and programmed instructional techniques. The dependent variables of interest were knowledge and skill acquisition. Analyses of posttests showed significant increases in learning for both groups followed by significant drops in achievement on a delayed retention test. There were no statistically significant differences between the two methods on any of the cognitive variables investigated. The authors concluded that CAI can be as effective as more traditional approaches for teaching factual knowledge and applications of learned material. They also stressed that controlling the content of CAI materials may inhibit effective utilization of CAI; it is how CAI is used as opposed to its usage that may determine its efficacy.

Brebner, Hallworth, Woetowich, Mah, and Huang (1981) report on three experimental studies into the effectiveness of remedial CAI mathematics programs. The first study used a standard pre-post-retention testing assessment to measure performance and attitudes of students receiving adaptive CAI and traditional math instruction. The two groups were statistically equivalent on all performance measures. The CAI group did take less time and had more positive attitudes toward math. A second study compared adaptive CAI to individualized booklet instruction. A second independent variable of student versus computer controlled routing (teacher control for the booklet group) through the material was considered. Again, no significant differences between method of control conditions were found. Trends indicated, however, that CAI instruction resulted in higher performance, that student controlled routing was inferior, and that the student controlled routing booklet group expressed negative attitudes toward that method. The third study, comparing adaptive CAI to linear CAI, resulted in no significant difference. The overall conclusions indicated that CAI is no more effective than other techniques in terms of performance, but does reduce instructional time. The authors also suggest that too much branching (adaptive strategy) may be counterproductive and confusing to the student.

Deignan and Duncan (1978) compared CAI with programmed instructional text (PIT) and the traditional lecture method for medical training. Evaluations were made regarding performance, time savings, and attitudinal acceptance. CAI was superior over lecture in a medical laboratory training course and outperformed PIT in a radiology course. CAI time savings were 14% in the medical laboratory lecture and 12% over the programmed text group.

Kamm (1983) developed 50 CAI tutorial units in physics which he used in comparison with a mastery model version of the traditional lecture, i.e. lectures with retesting capabilities to ensure mastery of the unit material. The CAI model produced a decrease in course attrition and the number of unit assessment test retakes.

These studies do not conclusively indicate that CAI is a superior instructional methodology. Many studies conclude that CAI is just as good as any other instructional technique in terms of achievement. Indeed, when CAI is employed as a substitute to other strategies it is just an also ran. Edwards, Norton, Taylor, Weiss, and Dusseldorp (1975) found that 45% of the research studies they considered showed achievement gains when CAI was used to supplement traditional instruction, 40% showed no difference, and 15% reported mixed results. A comprehensive survey of alternate instructional media conducted by Jamison, Suppes, and Wells (1974) concurs. They concluded that CAI was effective in reducing instructional time while maintaining achievement. Moreover, when CAI replaces the traditional lecture, higher achievement does not necessarily result. CAI augmentation of the traditional lecture appeared to be consistently preferred over the extremes of all or no CAI. These authors also conclude that there is an overabundance of no significant difference studies and that CAI had not fulfilled its envisioned role. Despite an intervening decade, their conclusion is still appropriate.

In a review of 92 studies involving comparisons of various educational techniques, Kulik and Jaska (1977) found on the basis of final exam performances that 54 indicated superiority over the lecture format, 34 were equivalent, and only three were inferior. Of the five studies specifically involving CAI, two were superior and three showed no difference in final exam performance when compared to conventional methods. On average there was only a 4% increase in achievement over the lecture mode. In a meta-analysis of 59 CAI research studies, Kulik, Kulik, and Cohen (1980) found that a majority (37 of 54) favored CAI as a means of improving student achievement. In 14 of 54 studies there were statistically significant differences favorng CAI. Thirteen of the 59 studies provided data regarding course completion rates. The results were inconclusive in that no systematic increase or decrease in attrition was found for CAI as compared to conventional instructon. The most dramatic findings came in the area of reduced instructional time for CAI. On average, when CAI is substituted for traditional lecture, instruction time is reduced by one-third.

In one of the more comprehensive reviews of the literature Rapaport and Savard (1980) compiled data on the issue of CAI as a supplement to or replacement of traditional instruction, its effects on student retention, and its efficiency as an instructional delivery system. As a supplement to more traditional methods, 114 studies reported increased academic performance, three showed declines, and six found no significant difference. Nine studies indicated that CAI as a replacement was superior, 11 had inconclusive results, and there wasn't even one study that showed a decline in performance. Long term retention was negatively affected in 11 studies, positively affected in only two, and 22 investigations showed no appreciable difference. With respect to instructional time, all 21 studies that provided data found that students in the CAI environment worked approximately twice as fast as their lecture-based counterparts. The overall conclusion was that CAI as a supplement was superior to a total replacemet of conventional methods and that it proved to save instructional time without compromising academic performance.

Orlansky and String (1981) investigated computer-based instruction for military training. The intent behind computer-based training (CBT) is to educate to the level of conventional methods but in less time. Less instructional time implies less cost (instructor and student wages) and more time to engage in field training and applications. This review aggregates 48 Army, Navy, and Air Force studies in which CAI or CMI methods were used. Of the 40 CAI studies 39 showed equivalent or superior levels of achievement when compared to "lock step" lecture method. All eight of the CMI studies were equivalent to the traditional techniques. Since saving time is crucial to the military, all but four of the 48 investigations reported reductions in formal instructional time. CAI instructional time ranged from 31% longer to an incredible 89% shorter than the time necessary in the lecture-based sections. The median was a

30% reduction in time when the computers were used. Although CAI saved time (and consequently a projected $13 million per year) with no detrimental effects on achievement, the drop out rates were substantially higher than for the lecture groups. While retention may be a higher priority in academic institutions it is not of primary concern in military settings. The authors point out that the attrition/retention studies are suspect due to a generally higher attrition rate in the general military student population. These studies, however, lend support to the argument that computer-based education leads to higher attrition.

In summarizing the experimental results regarding comparisons of CAI to other instructional procedures there does appear to be a consensus on some issues. With few exceptions, CAI is as good as if not superior to conventional methods on the basis of academic achievement. When CAI is implemented in a supportive, supplementary role, achievement gains over non-CAI paradigms are convincing evidence of CAI's effectiveness. When used as a replacement the results indicate that CAI is equivalent to any other technique. Although few studies have investigated long term knowledge retention, there is modest support for the claim that instruction via computers has a negative impact (Edwards et al., 1975; Rapaport & Savard, 1980).

One of the major advantages for using CAI is the consistent finding of a time compression effect without any immediate decrease in performance. Although savings of instructional time have their extremes, an average savings of 30-35% is frequently reported. One could argue that because there is a substantial reduction in formal instructional time requirements, student retention in CAI courses should increase. The research literature does not support such a hypothesis. Indeed, the literature reveals that CAI has no systemic impact on student retention. Even though the results are mixed, drop out rates are probably influenced by factors other than instructional methodology.

Strategies for Optimizing Instruction

As mentioned in the historical perspective, there have been two predominant schools of thought on the control of instructional content and sequencing. Since the computer has the capability to make decisions, then why not utilize this feature to determine not only when but what instructional event to present to the student? These decisions can be made at that point in the learning activity when and where it is optimal. Other researchers do not wish to second guess individual learners and therefore leave such decisions as what to study, in which order, and when to take the assessment tests entirely to the student. The debate becomes one of program versus learner control or to what extent should each one have its influence.

Atkinson (1972) contrasted three CAI sequencing strategies in the learning of German-English vocabulary pairs;

random order; learner-controlled; and response-sensitive. The experiment consisted of four learning trials followed by a delayed retention test. The random order strategy was superior in terms of initial performance while the response-sensitive method was the worst. Just the reverse was true on the delayed retention test.

The results were not unexpected. During instruction the learner-controlled strategy permitted the student to select which items to study--usually those that were missed on a previous trial. The same applied to the response-sensitive strategy. The randomized procedure not only presented cases which were initially answered incorrectly but also pairs which the student correctly matched. The delayed retention test presented all of the vocabulary pairs, thus measuring how much of the list was actually mastered. The response-sensitive or adaptive model had proved its effectiveness. The fact that the learner-controlled strategy was weaker was attributed to the students being poor judges and consequently poor decision-makers regarding their level of understanding or actual progress. Brebner et al. (1981) reported similar findings in a comparison of computer versus student controlled routing through mathematics material.

Judd, Bunderson, and Bessent (1970) developed three units of mathematics instruction in which four control strategies were compared. The two extremes of program control and learner control were studied, as well as two strategies mixing the two. Total learner control consisted of being able to select the instructional unit and which segments within that unit to study. The student could also skip around within the segment, i.e., skip over questions, jump to new problem sets, go back to the beginning of the segment, etc. The order of the instructional units and the sequence of events within the units were predetermined for the other three control versions. On the basis of a pretest, both of the mixed control strategies were routed through the materials under program control. Both of these groups, however, were advised as to whether the instructional segment should be studied. If the learner elected to enter the segment the instruction was subject to the predetermined order. One of the groups could skip around within the segment while the other was forced to proceed through the segment under program control. The order in which the segments were presented, however, was according to the preprogrammed sequence. Under complete program control the order of units, unit segments, and problem sets were presented in the preset order.

Although there were minor differences in achievement between the various control models for the three mathematics units, the authors concluded that all of the learner-control conditions were equivalent. The equivalence of the control strategies indicated that the students were capable of making sound decisions regarding the amount of practice they required on specific topics. From a programmatic vantage point the learner-controlled systems were of little academic benefit over predetermined sequencing. The recommendation forwarded was that a certain degree of program cotrol should be used to direct students through material that may be new or of proven difficulty for the individual learner.

Following this recommendation, decision-making capabilities were eventually designed (Tennyson, 1975) and incorporated into the management of instruction through the use of Bayesian statistics (Rothen & Tennyson, 1978). Unlike the program control strategies, adaptive control systems constantly adjust the number of instructional events the student will receive on the basis of the individual's on-task performance. As students work through the instructional units, those students doing poorly will automatically receive more exercises, problems, or explanations; students doing well will receive less.

Tennyson and Rothen (1977) investigated the effectiveness of adaptive systems by contrasting two adaptive designs and a non-adaptive model. A full Bayesian adaptive model, using data from a pretest and on-task information, and a partial adaptive design using pretest information only were compared with a program control paradigm in which students receive the exact same sequence of instruction. The results of the study convincingly demonstrate the effectiveness of the full adaptive control condition. Higher achievement levels in less time were statistically significant over the other two techniques.

Park and Tennyson (1980) extend this line of research by comparing different methods for initializing the adaptive control strategies. The number of examples selected in a concept learning activity was determined on the basis of pretest data only, on-task student input only, and a combination of the two. For the pretest only group, the number of instructional events once calculated remained fixed throughout the experiment. The other two groups had the number of events modified during the learning activity. The empirical data indicated that while pretest information reduced the on-task time and the number of examples presented to the students, the on-task only data source proved more efficient in terms of total instructional time and total number of questions needed (the pretest made the difference). There was no difference in the overall performance of any of the groups. Although the three information sources used to drive the adaptive control models were equivalent in terms of achievement, the concept of adaptive control proved efficient with respect to the time and the number of learning events.

Tennyson, Tennyson, and Rothen (1980) investigated the effectiveness of two dichotomous control strategies. The type, amount, and sequencing of instruction according to a totally adaptive procedure were compared to a system under complete learner control. Students receiving materials administered under the adaptive CAI model outperformed students in the learner-control group. The learner-control group took less time to complete the materials due in part to their ability to leave the instructional units and proceed to the posttest. The reduction in time resulted in poorer achievement, however. In this study, students given absolute control over the instructional process tended to make inappropriate decisions regarding their level of understanding and did not effectively use the instructional time or the available CAI capabilities.

Even though the extreme case of total adaptive control appears to optimize performance, there are some drawbacks. Instructional time is not necessarily optimized and, more importantly, the student is relieved of all decision-making responsibilities for his or her own learning. If adaptive and learner control strategies represent the extremes of a continuum, how effective would a hybrid of these two models be? The problem with the learner-controlled system seems to be the students' inability to make appropriate decisions, usually by overestimating their level of understanding. If an adaptive control system can make decisions, then a learner-adaptive control strategy in which the learner makes decisions based on diagnostic and prescriptive information may optimize time and performance (Tennyson & Rothen, 1979).

Tennyson (1980) experimented with the three management strategies of adaptive, learner, and learner-adaptive methods. The learner-adaptive and learner-controlled conditions permitted students to make decisions regarding the sequencing and the amount of instruction they received. The distinction between these two strategies is that students in the learner-adaptive group were advised of their learning needs in relationship to an established criterion level. Essentially the computer operated in the adaptive mode "thinking out loud", making recommendations, and giving the learner the option of taking or ignoring the advice. The learner-adaptive model not only gave students control over the amount and sequence of instructional material but also provided advisement, diagnosis, and prescriptions relative to a preset achievement level on which to base their decisions. The learner-controlled strategy indeed proved to be inferior to the adaptive models with respect to achievement. The learner-adaptive model required less instructional time and fewer examples than the adaptive strategy, but more than the learner control method.

In a subsequent study Tennyson (1981) replicated and expanded these findings. An experiment was conducted in which the adaptive model was replaced by a learner-partial control method whereby the introductory sections of the material were under strict program control but the practice sections were under student control. Using three units covering rule learning in English, the learner-adaptive strategy maintained its superiority in terms of performance. On-task time for the learner-adaptive group was longer than for the learner-control group, but less than the learner-partial control subsample. Moreover, the performance scores of the learner-partial control group were not consistantly better than those of the learner-control group.

In a review of learner control in CAI environments, Steinberg (1977) identified certain trends even though nothing was of statistical significance. In a learner controlled setting students took longer to complete a course (not necessarily CAI lessons) and did not perform as well as students in computer controlled situations (program or adaptive control). Students did not seem to accurately assess their knowledge of, or progress toward, course objectives. If students were given control over the level of instructional difficulty, they tended to make improper choices regarding their ability by working on units that were either too hard or too easy. Obviously these observations are more acute for the poorer learner or when the subject material is new to the students.

Decision-making procedures in the adaptive paradigm focus on previous and/or current performance within the learning task. Information processing or mathematical learning models, in contradistinction, rely on the modeling of cognitive structures and methods of thinking (Atkinson, 1972; Suppes, Fletcher, & Zanotti, 1976). The emphasis of these models is to develop predictive mechanisms for individual student progress within a subject area. Predictive capabilities would then permit control over time/resource allocation so as to optimize the grade-placement gain of an individual student. Suppes et al. (1976) developed a stocastic differential equation indicative of the progress students make through a CAI curriculum. The quantitative model produced an equation characteristic of the CAI material but constrained by student parameters. The model was tested using 297 deaf students involved in a 14 strand CAI elementary mathematics package. The theory does surprisingly well in predicting the number of CAI lessons completed to grade placement.

Predictive equations based on individual parameters were significantly better than the predictions generated from population parameters. Population parameters, however, produced an equation better suited for prediction purposes. The trajectory model, based on population parameters, provided a means of investigating student progress through the instructional materials and may impact on the quantitative details of course organization.

In a subsequent study Larson, Markosian, and Suppes (1978) used the trajectory model to fit performance data of college undergraduates in a logic course. The model was able to fit time data rather well, lending support to the use of such predictive measures as a control mechanism in the allocation of CAI access time given resource limitations. The trajectory model was found to be relatively stable after the first third of the course and may prove useful to students in assessing their progress within a course.

A theoretical extension of the trajectory approach is forwarded by Malone, Macken, and Suppes (1979) in their discussion of six CAI time allocation strategies. Following Atkinson's (1972) lead, each strategy was geared to the optimization of some aspect of class performance. The six models investigated were 1) maximize mean grade placement, 2) minimize variance in grade placement, 3) maximize mean grade placement without an increased variance, 4) maximize the number of students at or above grade level, 5) maximize the number of students making a specific gain, and 6) an equal time paradigm for all students. These researchers used a grade placement equation based on CAI access times and individual student parameters to make the necessary predictions. The theoretical results indicated that little was to be gained by using anything other than the equal time option. A simple increase of CAI access is probably more effective than utilization of specialized allocation strategies that would benefit only a few students.

Clearly, different control strategies focus on distinct aspects of instruction. As internal management strategies of CAI lessons go, the learner-adaptive technique appears to optimize both on-task time and performance while providing students the freedom and responsibility to make decisions regarding their education. The learner control aspect of instructional management can be of benefit provided that the students are continually informed of their progress and that the system provides meaningful advice on which to base sound decisions. Decisions made in the absence of information (learner control) are clearly less desirable and inefficient at improving performance than the data driven adaptive models. The other extreme of program control, albeit adaptive control, also seems ineffective at minimizing on-task instructional time. Since the adaptive strategy yields no apparent gain in performance, any management model that minimizes time would be preferable. The learner-adaptive technique provides such joint optimization of achievement and time reduction.

If college and university administrators are confronted with insufficient resources, then trajectory models would be of benefit in the planning, allocation, and management of those resources in a way that is justifiable and equitable to all parties. The control strategies of Tennyson and his colleagues focus on optimizing student learning and knowledge acquisition within CAI lessons. A coupling of these two techniques providing learners information on their progress within CAI lessons as well as within the larger context of a course or curriculum would be of obvious value.

Feedback Options

One of the highly touted features of CAI is the ability to provide immediate feedback. Linear systems can inform the student of the correctness of an input answer. Branching systems are capable of diagnosing errors and moving to the appropriate remedial section of the material. Some of the most sophisticated systems of the knowledge based or intelligent generation will actually question the learner about his or her input and/or direct the student through the subject matter. The unique features of computer technology, however, make possible the parameterization of feedback.

Gaynor (1981) contrasted four feedback conditions with performance on long and short term retention of mathematics material. The four treatment groups received 1) no feedback at all, or feedback 2) immediately after each question, 3) thirty seconds after each item, and 4) at the end of the CAI unit. On the seventh day of the study a short term retention test was administered and a long term retention test followed two weeks later. When student entry levels were equated there were no significant differences in either long or short term retention of the material. Two trends did emerge from the analysis. Immediate feedback produced slightly better retention scores for lower ability students while end of unit feedback benefitted the more capable learners. The second trend was a slight decline in performance scores for the 30 second delay group. Although not significant in a statistical sense, it did raise the possibility that such a delay may be counterproductive. When large computers become overloaded due to a high number of users, the delay induced may be detrimental to effective learning. Of interest, however, is the unexplained result that the group which received no feedback whatever performed just as well as students in the feedback conditions.

Rankin and Trepper (1978) set up immediate, 15 second delayed, and end of session feedback conditions in their study of knowledge acquisition of sexual facts. Their dependent measure was a 24 hour delayed retention test. The experimental results indicated that all three groups performed the same during the instructional trials but that the delayed feedback groups did significantly better on the retention test; there was no significant difference between the two feedback groups. The longer delay group, however, did have higher retention test scores and a smaller standard deviation than the 15 second delay group.

Sturges (1978) used two second, end of session (20 minutes), 24 hour, and no feedback conditions. The dependent measures were an initial test score, the score on a criterion test given 24 hours after the initial session, and the score of a retention test given one to three weeks after the conclusion of the instructional period. Long term retention was not enhanced by immediate feedback. Delayed feedback, however, promoted long term retention without retarding learning. The results supported what is known as the delay-retention effect (DRE) observed in other studies (Kulhavy & Anderson, 1972; Markowitz & Renner, 1966; Sassenrath & Yonge, 1968; Sturges, 1969, 1972; Sturges, Sarafino & Donaldson, 1968; Surber & Anderson, 1975).

These studies have far reaching ramifications in learning theory, curriculum construction and presentation, and the design of learning environments. Of particular interest is the implementation of delayed informational feedback within CAI environments. All of the above referenced studies adjusted the time of the delay and in all cases feedback was automatically administered. None of these studies allowed learner control over the timing or amount of feedback. The unique capabilities of computer systems for controlling the delay and extent of feedback as well as the use of remedial sequences will certainly facilitate further research into the delay-retention effect.

Anxiety and CAI

Since 1956 the United States has been an information based society in that white-collar workers employed in the creation, processing, and transmission of information out-numbered blue-collar workers (Naisbitt, 1982). The change from an industrial society to an information society has progressed slowly, being barely noticed. The advent of microprocessors has changed an evolutionary process into a modest revolution. Microprocessors are used for control systems in practically every electromechanical device. Despite this influx of technology, major portions of the American society remain apprehensive about computer systems. There is a widening gap between the technically literate and technically illiterate members of our society, hence, the term "computerphobia" has been added to the vernacular. In recognition of this fear of computers, educational systems and software companies have created computer literacy courses and user friendly systems.

One major area of research has been based on the hypothesis that performance in a CAI environment could be improved by designing instruction responsive to learner characteristics. Anxiety has been one of the most frequently researched personality variables. Spielberger, O'Neil, and Hansen (1972) report on four studies involving CAI and anxiety levels. One study compared anxiety levels in a CAI task versus subsequent performance in a laboratory situation. The lab setting was more anxiety provoking as measured by A-trait and A-state scales. Other experiments investigated performance within CAI lessons of high and low A-trait students. Performance on CAI tasks was a function of A-state level (high A-trait students typically have elevated A-state levels) and task difficulty with high A-state students doing poorer on the harder tasks; no relationship was observed for easy tasks. None of the studies found any systematic relationship between A-trait and achievement in CAI units.

Results of two experimental studies are presented by Leherissey, O'Neil, Heinrich, and Hansen (1973) which focus on the interaction of anxiety and several CAI design parameters. One of these variables was user response mode to questions presented. Four possible options were used: no response; covert (blank spaces for students to "think" the answer); modified multiple-choice, and constructed response (student types in the answer). Instructional materials consisted of familiar subject matter or technical information. High A-trait subjects had higher levels of A-state anxiety and the technical materials invoked a higher A-state differential (between high and low A-trait subjects) than the familiar subject matter. Students in the no response and constructed response groups performed better than subjects in the covert or multiple-choice treatments. Students in the constructed response group had consistently higher A-state levels.

A second design parameter studied was the length of the CAI units. The no response and constructed response groups were used in this study in which long and short versions of the instructional materials were compared. Students in the no response groups performed better than the students in the constructed response groups and completed the assignments in about half the time. Shortening the length of CAI units was not effective in reducing state anxiety. The no response mode was less anxiety producing and led to better performance. In these studies on-task instructional time was not considered a critical variable for reducing state anxiety or improving achievement.

Steinberg (1977) reviews several studies investigating anxiety levels under CAI learning conditions. One finding, which is not endemic to CAI, is the strong relationship between A-trait and A-state levels. On-task errors of high A-state students can be reduced by the use of various feedback techniques (Leherissey, O'Neil & Hansen, 1971) and A-state levels can be reduced by providing feedback on the more difficult tasks (Hansen, 1974). The overall conclusion, however, is that anxiety has little usefulness in the design and presentation of CAI materials. Tobias (1973a) states: "...that anxiety, while useful in other areas, has limited utility in the area of individualized instruction" (p. 237).

Summary

The research opportunities afforded by computer-based systems have opened diverse areas of design and application. This review has not focused on any specific academic discipline, grade level, or implementation strategy. The intent has been to introduce the reader to the diverse research areas, factors that can and are being studied, and some of the empirical data available to date. There are several reviews and meta-analyses of the literature that address the efficacy and effectiveness of CAI as a practical instructional methodology. Interested readers are referred to the reviews of Burns and Bozeman (1981), Chambers and Sprecher (1980), Edwards et al. (1975), Jamison et al. (1974), Kulik and Jaska (1977), Kulik et al. (1980), Orlansky and String (1981), Rapaport and Savard (1980), Steinberg (1977), and Vinsonhaler and Bass (1972).

There is overwhelming evidence supporting the position that computer-assisted instruction is extremely efficient at delivering instruction or training in a shorter time without compromising achievement. There is also an increasing number of studies which support the premise that CAI is an effective educational tool, but little evidence that CAI is superior to other methods. Research into instructional control strategies indicates that a learner-adaptive approach maximizes achievement while minimizing on-task instructional time. Control techniques for the timing and amount of informational feedback and its impact on the delay-retention effect can be easily studied using computer technology. Research into how student characteristics (anxiety, general ability, introversion-extroversion, field-dependence, etc.) interact with CAI, although limited, has failed to identify any specific affective variable that could be used in a predictive sense. Regardless, the time compression and delay-retention effects as well as instructional control techniques and hardware capabilities have been the focal point for many CAI activities and the development of more sophisticated computer-managed instructional systems (Baker, 1981).

Kearsley, Hunter, and Seidel (1983) summarize two decades of computer based instruction research. A few of their conclusions are pertinent to this review.

1. Computers can provide for more efficient and effective instruction (time, cost, achievement, resource usage, etc.).

2. Despite claims for individualization we really know very little about how to do it.

3. We have little knowledge regarding the impact of graphics, speech, motion, and other instructional variables.

4. Computer-based instruction has involved all areas of instruction and training for both research and applications.

5. The use of computers for education is still in its infancy and as such offers tremendous potential, which even after twenty years we don't fully recognize or completely understand.

Only through continued research efforts can we gain the insights and knoweldge necessary for the full development and utilization of computer-based education.

Aptitude-Treatment Interactions

Research Methodology

The previous two sections of this literary review have presented few conclusive results regarding achievement, despite the abundance of research data. A possible explanation for the inconclusive findings is that much of the research tries to determine the "best" method of instruction. Indeed, much of the CAI literature seeks to determine whether CAI is better than alternate methods or to decide which design features work best for "most of the students." Irrespective of the potential offered by computers for individualizing instruction, efforts to actually do so have been largely unsuccessful. The problem may not be with the method or the design features but in the application.

Recognizing and planning for individual differences and administering the "package" to all students seems contradictory. If instructional systems are designed to differentially impact on the student population then it would be appropriate to apply the methods in a differential fashion. Given the presence of a diversity of instructional techniques and an equally diverse student audience, it is highly improbable that one method works best for all students in all situations.

An effort directed at determining the optimal match of learner and instructional characteristics is generally known as aptitude-treatment interaction (ATI) research. ATI is not a separate, clearly defined research area but a methodological approach to doing research. Cronbach and Snow (1977) provide a description of the method and evaluation techniques used in aptitude-treatment interaction research. They also provide a synopsis of ATI research findings and their implications for education. The goal of ATI research is to generate regression equations that can be used for the prediction of effective and efficient teaching methods on the basis of individual differences. The intermixing of student learning styles, teaching technique, curriculum design features, and situational factors influences achievement. Hence, the ATI approach attempts to empirically define the optimal mixture.

ATI research data are often statistically cast into linear (occasionally curvilinear) regression equations.

Regression equations are generated for each of the experimental treatments. There are three basic possibilities available when these regression lines are plotted on an aptitude versus outcome graph. If the two regression lines are parallel, then no interaction exists and the treatment that yields the desired results should be used for all students. If interactions occur they can be either ordinal or disordinal. In an ordinal interaction the regression lines are neither parallel nor do they cross each other within the range of values present for the aptitude measure. In this case a differential utilization of the treatments may be in order but the decision cannot be based on the aptitude measure alone. Other factors, such as treatment costs or duration times, resource availability, etc., must be considered in deciding whether multiple treatments are going to be supported, and if so, what student assignment procedures are to be used. A disordinal interaction occurs when regression lines cross within the range of the aptitude measure. Differential effects of the treatments, however, are not only dependent upon those factors mentioned for the ordinal interaction, but also on the statistical and practical significance of the interaction itself.

ATI research covers such a wide range of activities that the terminology is not uniform across studies. Berliner and Cahen (1973) in their review use the term trait-treatment interaction (TTI) although they prefer trait, treatment, and task interaction (TTTI). Tobias (1976) replaces aptitude with achievement in the ATI acronym and has proposed the term attribute as one connoting a more universal meaning. Even though these terms appear in the literature and have subtly different meanings, they all convey the idea that individual characteristics and educational treatments may interact and that these interactions may have potential use in how we, as educators, can better teach our students.

Salomon (1972) argues that ATI research serves the two functions of improving instruction and developing principles concerning the nature of instruction and learning. He elucidates on three ATI paradigms: remedial, compensatory, and preferential. The remedial model assumes some missing element is responsible for a student's lack of progress through hierarchical or structured materials. The thrust of this model is to identify and fill the knowledge gap while minimizing time (and cost). This approach, however, is applicable if the variance in learning outcomes is directly related to task-specific capabilities, if the subject matter is hierarchical in nature, and if the subordinate skills are indeed learnable through instruction. Notice that this model does not necessarily rely on cognitive or personality characteristics, but focuses on expedient techniques for overcoming educational deficiencies.

The compensatory model employs various treatments which have been designed to circumvent ineffective and unproductive aspects of other treatments or learner abilities. The treatment compensates for student deficiencies by presenting the material in an organized way; one that the student may not be able to provide for himself. For example, a well structured presentation with detailed feedback and a high degree of redundancy may benefit students who are unable to synthesize or organize the material on their own. Such a treatment, while helpful to one type of student, may be detrimental to the learner who can effectively provide the necessary structure on his or her own. In this model, aptitudes play a greater role than in the remedial model. This model is not concerned with changing student capabilities, just compensating for the deficiencies. The choice between the remedial and compensatory models rests on whether the learning capability (if identified) can be taught or simply averted.

The preferential model is used to capitalize on existing student capabilities. It does not make up for deficiencies or circumvent them but attempts to match treatment characteristics with individual learning styles. The aptitude measures for this paradigm typically consist of general ability, mode of information processing, and motivational factors. The intent is for each student to maximize his or her learning through the appropriate assignment of treatment conditions. Tobias (1976) labels this approach as the alternative abilities model, in which instructional treatments are designed to engage different student abilities and interact with student aptitudes to produce higher performance scores.

From a theoretical point of view, ATI research would appear to hold the key to determining the method-situation-student mix that is optimal for learning. Tobias (1976) laments, however, at the lack of interest in ATI by writing, "Despite this persistent interest in individualized instruction, there are few systematic attempts to adapt the method of instruction to student characteristics" (p. 61). McCombs and MacDaniel (1981) state:

> While much has been written concerning the desirability of an aptitude-treatment-interaction (ATI) approach to the individualization of instruction...there has been a notable lack of effort toward addressing the way educators could implement such an approach. (p. 11)

They proposed a computer-based training program which was an adaptive system couched in the preferential ATI model. Stepwise regression procedures on selected cognitive and affective pre-course characteristics were used to predict performance scores and unit completion times. Alternate instructional strategies differed in media form, format or style, difficulty, and/or use of special learning aids. Design features of the system allowed for low reading/processing ability, low memory ability, and high test anxiety. The adaptive nature of this system did accommodate individual differences and led to higher achievement in less time. This type of approach parallels the adaptive system techniques of Tennyson and his colleagues discussed in the previous section.

The preferential ATI model appears to be receiving much of the research attention, especially for CAI applications. Research findings, however, are far from corroborative, much less conclusive. The next two sections will present some of the research findings, particularly those involving locus of control and/or computer-based instruction. For a more detailed treatment of the theoretical background and analysis techniques as well as a comprehensive review of the literature, interested readers are referred to the Cronbach and Snow (1977) text and the Berliner and Cahen (1973) article.

Ability by Treatment Interactions

A wide range of studies which have some measure of ability as the predicting variable can be grouped together. Ability may be formally measured via standardized tests (SAT, ACT, IQ, etc.), teacher made pretests, or GPA's. One of the larger areas of ATI research involved programmed and computer-based instruction. In most of the studies these instructional methods have been compared to other techniques, thus constituting treatment contrasts. However, there is a significant number of reports that use one specific delivery mode and investigate design variations. Tobias (1969) and Tobias and Abramson (1971) used programmed instruction to study the interactions of response mode (reading the answer versus constructing the response) and the level of familiarity with the subject material. The programs consisted of approximately 55 frames of familiar material and roughly 90 frames of technical material of which the students knew very little. Both studies indicated an attribute-treatment interaction on the unfamiliar technical material favoring the constructed response mode. There was no difference in posttest scores based on response mode in the more familiar materials. This form of ATI would possibly be classified as an ordinal interaction in which the constructed response mode is clearly favorable for material that is foreign to the students.

Tobias (1973b) investigated the use of scrambled versus structured frame presentations on familiar and unfamiliar materials in a PI format. As one might expect, significant attribute-treatment interactions were found for the sequencing of PI frames but on the unfamiliar materials only. The study also considered whether generalized ability, as measured by the SAT, would serve as a stable predictor of achievement. No ATI involving SAT scores was observed.

Tobias and Duchastel (1973), working in a CAI environment, questioned whether the use of behavioral objectives interacted with the sequence of familiar and technical materials. The expected ATI between the use of behavorial objectives and sequencing was not found. Sequence, however, did have a significant main effect for students receiving the technical materials. Despite the absence of any ATI's, the authors suggest that the CAI and PI techniques demonstrate strong sequence effects on materials of a technical nature.

In an early study involving CAI, PI, and standard textbook instruction, Schurdak (1967) used scores on the college level form of the Henmon-Nelson Mental Ability test as the main determinant of achievement. Although CAI was clearly the best treatment on average, no significant ATI's were found. The analysis revealed, however, that all three methods were equivalent for students with Henmon-Nelson scores above 80, while CAI was superior for students with scores below 80.

More recently, Deignan and Duncan (1978) conducted a study comparing the effectiveness of CAI, programmed instructional text, and lecture methods. A series of pre-treatment aptitude measures was used to artificially define a tertiary aptitude scale. Although the design and analysis of this study was not in the preferred ATI context, results indicated that low level aptitude CAI students had an 18% higher achievement level over their lecture counterparts and 7% higher achievement with 17% greater time savings than the programmed text group. High aptitude CAI students had a 33% time savings over the lecture group. These inferred disordinal ATI's support the recommendations to assign CAI for low ability students and programmed text to middle and high ability students if achievement is the criterion. CAI would be used regardless of ability level if time was the criterion.

Masuo and Furuta (1981) designed and conducted an ATI study involving CAI and PI as treatment variables and a pretest of the subject matter as the ability or aptitude measure. Regression analysis indicated a significant disordinal ATI for posttest scores on the basis of pretest scores and treatment method. CAI was a superior method for the low pretest scorers while high ability students benefitted from either instructional mode. The pretest measured the students' levels of previous knowledge and can be interpreted as a level of familiarity with the subject matter. Viewed in this context, this study supports the work of Tobias in that differential treatment effects occur in unfamiliar subject areas while no one particular instructional system is preferred by students of higher ability. The possibility exists that the differential effects are indeed present but the more capable students are able to compensate for the variations in technique.

In a study of mathematics instruction Battista (1981) presented materials requiring spatial visualization (rotations of three dimensional objects). The ability measure was a specially constructed exam assessing student capability for spatial visualizations. One group of students received verbal instruction without the use of any visual aids. The second treatment group received verbal lectures supplemented by as many visual-spatial aids as possible. No significant ATI's were observed although the treatment regression lines did cross, indicating a possible disordinal interaction. The ATI suggested that students of high pre-treatment spatial visualization ability performed better in the verbal only method of instruction, a reversal of the predicted result. Explanations for the non-significant, reversed ATI trend included a subject material dependence, differing mental process requirements of the treatments, and task difficulty differences.

Janicki and Peterson (1981) investigated large versus small group instruction for the presentation of math materials (fractions). A three level blocking on ability was employed based on scores from Raven's Progressive Matrices and the Sequential Tests of Educational Progress. The large group treatment involved lectures and individual seatwork. The small group treatment used lectures but seatwork was done in groups of four students: one high ability, two medium ability, and one low ability. With respect to achievement, an ability by treatment interaction was non-existant. In a similar study involving geometry instruction, Peterson, Janicki, and Swing (1981) measured a curvilinear ATI between achievement and ability. The small group approach was preferred by students in the low and high ability groups while the middle ability students performed equally well in either treatment.

In a review by Cronbach and Snow (1977) 32 studies comparing programmed instruction and conventional techniques are documented. The studies ranged from one hour to one year in duration. Thirteen studies reported PI regression lines with slopes less than those for conventional instruction. Four studies reported significant ATI's, eight showed weak or non-significant ATI's, and one was noncommittal. Students of lower ability performed better in all 13 of the non-conventional modes. High ability students were not differentiated by treatments on 12 of the studies. Five of the 32 studies reported PI regression lines with slopes greater than conventional instructional methods. Two studies quoted significant ATI's while the remaining three showed weak or non-significant interactions. In four cases low ability students performed better in conventional classes. High ability students had higher achievement levels in all five of the non-conventional methods. Fourteen of the 32 reports showed no interactions. In 25 of the 32 studies the ability measure was useful in predicting academic achievement in the non-conventional instructional treatments.

Cronbach and Snow (1977) also report that ATI research into variations within the PI treatment has generally ended in failure. Effects of branching versus linear programming, small detailed steps versus large steps, scrambled versus logical sequencing, reading versus constructed response, etc., have generally proved inconclusive. The generalized claim that PI would allow low ability students to overcome any difficulty and achieve as much as high ability students receives little support. There have been isolated studies that support this contention but a comprehensive review of the literature most often produces studies with no interactions, or, when interactions exist they are usually weak and rarely consistent from study to study.

Computer-based instruction is the natural extension of programmed instruction and as such, research findings in which CAI is one of the treatments are no more definitive than those of PI. Since a majority of educational research efforts are correlational or of the "one best method" type, many of the interactions reported are not the product of an overt ATI design. Moreover, regression equations are generally not presented in the event of significant interactions nor is the necessary data for generating them. Most studies, even in those where non-significant yet non-parallel treatment regression lines occur, do not apply the Johnson-Neyman (1936) procedure to determine those extreme ranges of the ability measure which do produce significant differential treatment effects. Berliner and Cahen (1973) report on one study in which 84% of the students had ability scores in a non-significant region but where the Johnson-Neyman technique identified the extreme regions where significant differences were observed (8% of the sample at each end of the ability scale). Nevertheless, Burns and Bozeman (1981) found in a meta-analysis of 40 studies that when achievement is the dependent variable, the CAI treatment favored high achieving and/or disadvantaged students. Students of average ability performed well regardless of instructional mode. Edwards et al. (1975) and Jamison et al. (1974) agree that CAI appears to promote higher levels of achievement for low ability or disadvantaged students. Whether the ATI is linear or curvilinear remains open for further research.

Personality by Treatment Interactions

A second major variable category for predicting achievement is personality traits. Personality variables are difficult to isolate because of their interactions with other personality measures. Anxiety is one of the most researched areas with respect to its effect on PI or CAI methodologies. The studies of Tobias (1973b) in a PI format and Tobias and Duchastel (1973) with CAI, used A-trait and A-state as the aptitude measure. Both of these studies failed to find ATI's for performance. Anxiety was influential in increasing on-task error rates in the CAI materials but not on posttest scores.

In their study of subject familiarity and response modes in a PI environment, Tobias and Abramson (1971) used Alpert and Haber's Achievement Anxiety Test (AAT), composed of facilitating and debilitating anxiety subscales. Facilitating anxiety did interact significantly with response mode (reading versus reinforced constructed). Debilitating anxiety was neither a significant main effect nor was it involved with any interactions. The authors conclude that their study along with others (Ripple, Millman & Glock, 1969; Steinberg, 1977) provides little support for aptitude-treatment interactions between anxiety and programmed instruction.

In a PI environment Tobias (1969) investigated the applicability of creativity, measured by the Remote Associates Test, for predicting achievement in different instructional response mode treatments. The hypothesis that highly creative individuals would do poorly in a constructed response format (as opposed to simply reading the answers) while less creative students would do better was not supported. Creative students obtained higher achievement scores regardless of response mode.

Ripple et al. (1969) contrasted conventional instructional and PI strategies in an attempt to identify disordinal interactions based on exhibitionism, compulsivity, and convergent minus divergent thinking. Programmed instruction was hypothesized to produce higher achievement scores for students with low exhibitionism, high compulsivity, and high levels of convergent minus divergent thinking. None of the 36 separate analyses dealing with these three characteristics were significant; conventional instruction proved to be superior to PI in all cases.

Domino (1971) sought interaction effects between achievement orientation and teaching style. Extremely high and low scoring students on the achievement-via-conformity and the achievement-via-independence scales of the California Psychological Inventory were assigned to lecture sections taught in either a conforming or independent manner. A significant disordinal interaction resulted, as well as a consonance between student orientation and instructional methodology which led to higher academic performance. The "congruence" concept discussed in the review of the locus of control literature seems to parallel these findings. Internal students performed better under skill conditions while external students worked better under chance conditions.

Hoffman and Waters (1982), in one of the few studies of the relationship between student affective characteristics and CAI, used the dichotomous scales of extroversion-introversion, sensing-intuition, thinking-feeling, and judging-perception as independent predictors. These four scores were derived from the Myers-Briggs Type Indicator instrument. Results of a seven week course showed that sensing type students had higher retention rates and quicker completion times. Extrovert/perceptive type students had the highest attrition. The thinking-feeling scale didn't appear to be an important factor. Even though the study is not of an ATI design, specific changes to the CAI materials for the extroverts, intuitive, and perceptive type of students were indicated in order to keep them motivated and interested.

Goldberg (1973) reports on an extensive search for ATI's between student personality measures and learning conditions. Over 800 students were assigned to two instructional conditions (lecture versus self-study) crossed with two methods of assessment (multiple-choice quizzes versus integrative papers). The personality measures, gathered from an extensive battery of questionnaires, inventories, and tests, yielded over 350 scores (students answered roughly 3500 items). Data from the three general dependent variable categories of course content knowledge, amount of extra-curricular reading, and degree of student satisfaction were collected. Despite what can only be considered a "shot-gun" research approach, the number of significant ATI's identified were less than the number expected by chance alone. Specially constructed personality assessment scales designed to elicit ATI's failed to do so in a cross-validation study. Unfortunately, the analysis technique used in the report was largely correlational and not regressional, even though the author addresses the different methods. The paucity of ATI's generated by such an approach is not only disappointing but confusing and difficult to interpret within any meaningful context.

In somewhat of a variable role reversal, Corno, Mitman, and Hedges (1981) questioned whether different instructional procedures could change levels of anxiety, self-esteem, locus of control, and attitude, and whether a measure of general mental ability was a viable predictor of such changes. A three level teacher training program and a two level learning skills program (administered by parents) were used as treatments. Significant ATI's were found for attitude toward school and anxiety as a function of general mental ability and the learning skills program. The relationship involving anxiety was a three-way interaction between general ability, anxiety, and the learning skills program. The results also showed no significant changes in the student locus of control variable. The study, despite the complexity of the results, lends support for the existence of ATI's between general mental ability, motivational variables, and instructional treatments. This and similar studies are important in that most ATI research uses measures such as anxiety and attitude as predictors rather than as dependent variables. This particular study, however, did not differentiate between state and trait anxiety, thus raising a question of the permanence and generalizability of the results. The fact that locus of control, considered a relatively stable personality measure, was unaffected suggests that a distinction between "state" and "trait" measures is in order.

Smith (1973) also investigated possible changes in student personality measures due to experiences in a CAI setting. The subjects were junior high school students of whom approximately 75% were from Mexican-American backgrounds. The sample was given the Sears Self-Concept Inventory, Coopersmith Self-Esteem Inventory, and a modified version of the Crandall Locus of Control Instrument prior to the beginning of a ten week mathematics course and immediately afterwards. Pretest-posttest scores for the non-CAI group were relatively stable. Posttest scores for students in the CAI group were less predictable for the self-concept scales and the locus of control measure. The author concludes that for the locus of control data, the slopes of the CAI and non-CAI regression lines were significantly different. The locus of control instrument consisted of three sections, modified versions of five items from each of the IAR+ and IAR- subscales, and the three item Fate Control Scale (Coleman et al., 1966). The locus of control measure is, therefore, a shorter, highly modified version of the original IAR instrument. Moreover, pretest-posttest correlations for the IAR+ and IAR- subscores were not significantly different for the non-CAI and CAI groups. The significance appears to be due to the three Fate Control items. Regrettably, no further discussion of what appears to be a significant ATI was presented.

Janicki and Peterson (1981) and Peterson et al. (1981) used the Academic Achievement Accountability locus of control questionnaire as a predictor of achievement for small versus large group instructional models. Both of these studies investigated several other personality and attitudinal measures. To reduce the multicollinearity of the variables used, a factor analysis was performed and a single factor of attitude toward math and locus of control was constructed. The factor loadings were .94 and .52 (Janicki

& Peterson, 1981) and .47 and .60 (Peterson et al., 1981) for the attitude and locus of control components respectively. The first study reported a significant disordinal ATI on achievement for the small versus large group instruction predictable on the basis of the attitude/locus of control factor. The small group method proved successful for 35.5% of the students in the study. The large and small group approaches were statistically equivalent for the rest of the students.

The attitude/locus of control measure revealed a significant disordinal interaction for scores on an attitude toward teaching approach scale. Students with positive attitudes toward math/internal locus of control preferred the large group method. Students with poorer attitudes/ external orientations preferred the small group approach. No ATI between achievement, the attitude/locus of control factor, and instructional approach was found; the achievement ATI reported by Janicki and Peterson (1981) was not replicated in the Peterson et al. (1981) study.

<u>Summary</u>

The intent of this brief review of ATI research was to provide a modicum of background information on the basic concept and goals of this research approach. If one assumes a normal bell-shaped distribution of performance scores, then one would not be in error in stating that 17% of the students do quite well, 66% do average work, and 17% never really get on track. Some would point to such distributions as an indictment of the educational system's inability to adapt instructional practices that account for individual differences. It is indeed foolish to attempt to eliminate or even mollify individual differences in learning. Moreover, educators can no longer ignore such differences. Bell-shaped distributions will always exist; it is the positioning of the distribution on the achievement scale that is important. It is also important to identify those ATI's which will truly benefit the students and the educational system in general.

Bracht (1970) reviews 108 ATI studies. Each study was classified according to three dichotomous scales: treatments (controlled or uncontrolled); personological variables (factorally simple or complex); and dependent measures (general or specific). Of the 108 research studies documented, 103 of them reported ordinal or no interactions and only five showed disordinal interactions. On the basis of these data disordinal ATI's were more probable for controlled treatments, i.e., subject to little external influence, and more probable for factorally simple personological variables, i.e., variables having low correlations with other personological variables. Since most of the studies had a specific dependent measure, little is known regarding the effects of the dependent measure. The ordinal interactions should not have been grouped with the no interaction studies because the possibility exists that significant treatment effects may be present for certain extreme sections of the aptitude variable (determined by the Johnson-Neyman technique) or that other indirect factors may have a substantial impact upon any decisions regarding support for different treatments.

Berliner and Cahen (1973) conclude their review of the literature by stating:

> In general, significant interactions are not a rare occurrence, and interactions have important implications for the design of instructional treatments. ...most studies of interaction have not been replicated; when replicated, interactions have not been confirmed. (pp. 84-85)

The research reviewed herein is clearly in support. The diversity of aptitude and personological measures, and the variations in instructional treatments creates an extremely complex network held together solely by the ATI philosophy. There appears to be very few rules; personality measures are used as predictors as well as dependent variables. Highly unstable and/or temporal variables are used as predictors, not easily generalizable even in the event of significant interactions. When significant interactions do occur they are rarely the product of an overt ATI design and they are seldom fully developed into useful regression equations.

For the factors pertinent to this study, CAI as a treatment is beneficial for students of lower ability or in need of remedial assistance. Most studies using CAI, or its predecessor PI, as one of the treatments typically fail to have any impact for high ability students. The reasons for these differential treatment effects is not clearly understood. Research into variations within the CAI methodology has been unsuccessful in identifying the causal agents. It may simply be the entire approach that assists less capable students to show increased performance. Lower ability students are probably utilizing CAI materials in the remedial or compensatory formats which appear to be unnecessary for students of higher ability.

Despite the desirability of the preferential model, little is actually known regarding its effective implementation; we simply don't have the knowledge or the ATI's on which to intentionally make student-treatment assignments. Reece and Gable (1982) developed an attitude survey which was used to elicit student feelings about computers. Factor analysis reduced a 30 item survey to a ten item general attitude toward computers questionnaire. This instrument was promoted as a means of identifying students for CAI assignments or general computer usage. Posner and Osgood (1980) comment that computer availability alone was not sufficient to attract student use and that many students were reluctant to use computer facilities. To overcome this problem they had to prepare a special course to provide a "threshold of familiarity with the computer" (p. 92). The task consists of formulating a theory which can be used to prescribe the effective and efficient use of current educational technology in a manner that is non-threatening and even inviting.

The locus of control variable has been used as both an independent measure and a dependent variable. Studies which used locus of control as an independent measure confounded the experimental results by pairing it with other personological measures. These studies, however, do imply that locus of control may interact with treatment methods to produce differential achievement effects.

Studies that treated locus of control as a dependent variable find it to be relatively stable over the duration of the experiment. These findings are important in that the locus of control concept appears to be a stable "trait" type of measure potentially capable of predicting treatment-dependent achievement while remaining resistant to change over the duration of the treatment.

The focus of this study is to investigate whether the personality measure of student locus of control interacts with the instructional treatments in a differential fashion. The ATI research model provides the requisite underpinnings that connect the variables, methods, and evaluation procedures. Tobias (1976) provides an appropriate quote to close this review of the literature by stating that:

> ...the bulk of the work remains to be done, and the viability of the ATI construct for the illumination of our understanding of instructional events, as well as for advancing practice to the point where instructional prescriptions can be made, is still to be demonstrated. (p. 63)

CHAPTER III

DESIGN AND PROCEDURES

Introduction

This chapter presents a discussion of the research questions and hypotheses, the experimental design used to resolve the questions, and the procedures followed in the preparation and execution of the study. Design aspects for this investigation involves the CAI delivery system, the courseware used, and the experiment itself. After a brief discussion of the research questions and the related hypotheses, these three design issues are presented. The experimental design over time and variables is developed. The statistical analysis procedures employed are then discussed as are the reliability and validity data of the assessment instruments.

Following specification of the independent, dependent, and covariate measures, predictions of the research results are presented. The chapter concludes with a discussion of the specific procedures involved in the preparation and implementation of the study and is provided to assist in the replication and/or continuance of this line of research.

Research Questions

The primary focus of this study was to investigate the interaction between student characteristics and the mode of instruction. The study specifically addresses the following questions:

1. Will the distinctly different strategies of traditional lecture and computer-assisted instruction differentially affect academic achievement?

2. Can levels of academic achievement be predicted for the different instructional techniques based on student locus of control measures?

3. Does there exist an interaction between instructional methodology and student locus of control?

4. Are the results generalizable across student samples?

Research Hypotheses

The review of the literature identified several factors that are results of, or directly related to, previous research efforts in the area of CAI. Prior knowledge, general ability, and on-task time have been linked to performance levels in CAI settings. Study or non-formal instructional time is one variable that is rarely considered or controlled in research studies. These variables as well as class performance levels, measured by scores on homework, quizzes, and unit tests, were measured and considered as possible covariates in the data analysis procedures. Additional measures of prior knowledge and ability considered were ACT and SAT math scores, the MSU math placement score, and the previous math course grade.

The independent measures were scores on the Intellectual Achievement Responsibility Questionnaire (Crandall, et al., 1965). This particular scale contains two subscales.

The I+ subscale is a measure of a student's acceptance of success. The I- subscale assesses the level of responsibility a student assumes for failures. A third score, I total, is the sum of the two subscale scores and indicates the degree of acceptance for successes and failures in academic settings. High scores on these scales represent an internal orientation, that is, success/failure is a direct result of the student's actions. Low scores indicate a student's belief that success/failure is not a direct result of his or her actions, but primarily due to external agents. These three scales were used in the analysis.

The treatments were the distinctly different educational delivery methods of traditional lecture and computer-assisted instruction. The dependent variable was student achievement on a specially constructed unit examination for a College Algebra course, Michigan State University course Math 108.

The following hypotheses are grouped according to the order of the research questions and the statistical design used in the analysis of the data: analysis of variance; analysis of covariance; and linear regression analysis. For the analysis of variance and covariance, the locus of control measure was used as a blocking variable in which students scoring above the sample mean on the IAR total score were classified as internal subjects. Those below the sample mean were classified as external subjects. This bi-level blocking is preferred for ATI research (Cronbach &

Snow, 1977) because it improves the power of the statistical analysis procedures by balancing treatment group cell sizes. This is particularly important when the total number of students involved in the study is small. The internal-external delineation is also typical of locus of control research (Rotter, 1975). Subject to these conditions, the research hypotheses for this study are:

1. There will be no difference in the mean achievement scores for students in the traditional lecture and computer-assisted instructional treatment groups.

2. There will be no difference in the mean achievement scores for students classified as internally or externally oriented on the basis of the total IAR score.

3. There will be no achievement interactions between instructional treatments and locus of control classifications; all students will perform equally well regardless of instructional method or locus of control orientation.

4. There will be no difference in the mean achievement scores for students in the traditional lecture and CAI treatments after covariate adjustments.

5. There will be no difference in the mean achievement score for internally or externally oriented students after covariate adjustments.

6. There will be no achievement interactions between instructional treatment and locus of control classifications after covariate adjustments.

7. There will be no difference in the slopes of the regression lines (academic achievement as a function of locus of control measures) for the lecture and CAI treatments.

8. There will be no extreme locus of control conditions where a differential application of instructional methodology is warranted based on significant differences in achievement scores.

Design

CAI System Design

The CAI system used in this study was developed and written by the author (Hamilton, 1981). The system is designed to be curriculum independent and to optimize computer capabilities via graphics, calculator functions, and instructional tailoring based on the academic history of the user. The system uses a 48K Exidy Sorcerer™ microcomputer and the Exidy Disk Display Unit. This unit contains a 12 inch P31 video monitor and a dual disk drive system. The system uses single sided, soft sectored, 5.25 inch disketts and operates under CP/M version 1.42/3. All software and courseware are stored on floppy disks as are all ancillary data management, student tracking, and analysis programs. All programs, with two exceptions, are written in Microsoft's MBASIC version 5.03. The exceptions are the main instructional delivery program and the instructional authoring program, both of which are written in Z-80 assembly language.

The goals of the computer driven delivery system are:

1. To provide a versatile instructional system for stand alone use or as a supplement to traditional information delivery methods.

2. To provide instruction on an individual or "tailored" basis.

3. To incorporate an instructional management system where the sequencing of materials is determined by diagnostic analysis of student input and performance history.

4. To optimize existing computer capabilities for educational purposes.

5. To create a system easy for student and instructor use.

The CAI delivery system does not contain the courseware used in the study. The delivery system simply processes the courseware units which have been created and stored separately. This separation of functions highlights the distinction between software (data processing programs) and courseware (instructional units). This separation also allows for a wide variety of subject matter and instructional designs to be prepared and investigated.

The CAI management system can present materials at three levels of difficulty depending upon the student's current capabilities. The system can raise or lower the difficulty parameter on the basis of student responses. The system uses this difficulty parameter to pre-configure an instructional lesson prior to its actual presentation, so there are intra-lesson adjustments. The program does not permit intra-lesson branching although inter-lesson branching is allowed. Inter-lesson branching can be forward, backward, or through the same lesson at the same or a different difficulty level. Sequencing decisions are based on algorithms provided by the curriculum developer and the decision-making procedure occurs when a lesson is completed. Decision algorithms can be prepared for sequencing, difficulty level adjustments, and in extreme cases, preparing a printed copy of the lesson for the student to take as study material.

The CAI delivery system also contains calculator capabilities, allowing students requiring assistance to use the computer to perform numerical computations. Mathematical expressions can be input by the user and evaluated by the system. The calculator mode supports six mathematics operations and ten functions.

The curriculum developer or course instructor can specify whether students have access to the calculator mode, control of forward and/or backward frame advances, and if the unit is to be presented according to the user's assigned difficulty level. These control options are an integral part of each instructional lesson. This organizational structure provides for a CAI delivery system which is subject independent, responsive to instructor control, yet sensitive to student ability.

Courseware Design

Courseware preparation often uses special processing codes (Hamilton, 1981) or "dot" commands (Jelden, 1981) for the identification and specification of text processing procedures. The CAI system developed for this study supports 18 such text processing functions. Appendix A provides a brief overview of the CAI system configuration and a description of the special text processing capabilities.

The courseware selected for this study covers subject material from the College Algebra course (MTH 108) offered under the auspecies of the Michigan State University Mathematics Department. The material covered during the last two weeks of the course was selected for the study. Three one-hour CAI lessons were prepared by the author which utilized the processing features of the software system. The subject matter was based on the lecturer's notes and the textbook (Hestenes & Hill, 1981). The six major topics and the CAI lessons were: Complex Numbers and Complex Roots of Equations (Lesson 1); Polynomials, the Remainder and Factor Theorems, and Synthetic Division (Lesson 2); and Zeroes of Polynomials and the Rational Root Theorem (Lesson 3). The courseware was prepared using a learning system design methodology (Davis, Alexander & Yelon, 1974). Each instructional lesson was composed of a linear series of frames or pages (a page could consist of several complete video screens of information) and the three lessons constituted a hierarchical sequence of learning materials. The first few pages of each lesson presented a list of objectives for the lesson and a list of references where supplemental information could be obtained. The body of the materials centered on the stated objectives as did the examples and problems within the lessons and the unit exam questions.

Required student response to questions and problems was analyzed for correctness. Most of the questions used a multiple-choice format. Occasionally a problem requested a numeric answer which had to be specifically typed in. Feedback was tailored to the specific response given. Correct answers were indicated by a short word of encouragement. Incorrect answers were countered with a brief discussion of the error and often helpful hints regarding the intent of the question. Most of the questions were capable of this diagnostic feedback approach. Feedback, however, was provided immediately after each item.

Since the instructional materials were of a mathematics nature, a random number generator was used to prepare different numerical values or to select textual phrases for insertion into problem or question statements. Students could work through the same lesson several times and, although the same problem might be presented, it would contain different numerical values, forcing the student to rework the problem. Courseware design often utilized a feature for randomizing the multiple-choice foils, thereby preventing memorization of the correct answer key or its position.

One unique capability of the computer-based instruction system is the ability to control the display of the steps presented in a problem-solving sequence. The computer would present one line of a multi-step sequence and wait for the student to respond before the next line was displayed. A textbook simply displays all the lines in the solution. This control aspect not only requires active student participation but it gives the learner the opportunity to work out the next step of the solution prior to having it displayed.

The courseware was also designed to allow students access to the calculator mode and to skip around within the lesson. The last page of each lesson contained a summary of the topics discussed and references to the position in the lesson of the major topics. This was included so that students wanting to review the materials and rework the problems could do so.

Research Design Over Time

The design over time describes the temporal sequence of experimental events (Campbell & Stanley, 1963). The notation used provides the relationship between treatments, measurements, and time. The dependent variable, achievement on a unit exam, was studied for each of the two treatment groups. Each of the groups were created by a stratified random assignment based on a dichotomized locus of control (LOC) scale. The IAR Questionnaire (Crandall et al., 1965) was used to measure student locus of control. Permission to administer this instrument had to be acquired from the University Committee on Research Involving Human Subjects (UCRIHS). Permission was granted and the appropriate documentation can be found in Appendix B. The following graphical representation describes the research design over time.

Lecture	SR	X_1	O
CAI	SR	X_2	O

The "SR" indicates that students previously classified as internal or external on the basis of their locus of control scores were assigned to treatments by a stratified random technique. "X_1" represents the lecture method of instruction while "X_2" is the CAI system. Lastly, the "O" indicates the achievement observation, i.e., performance on a unit exam. There are no subscripts for the observation because the same exam was taken by all students regardless of treatment assignment. The time line proceeds from left to right.

Variable Selection and Analysis Techniques

The research hypotheses presented earlier require three distinct methods of analysis, those being analysis of variance, analysis of covaraiance, and linear regression analysis. This experiment used the two distinct treatments of lecture and CAI and the artificially constructed two-level blocking variable of internal and external locus of control. The experimental matrix, therefore, takes on the form of a 2-by-2 completely crossed design. The design matrix is illustrated in Figure 1.

A two-way analysis of variance (ANOVA) performed on the achievement measure provides the means of addressing the first three stated hypotheses. The results of an ANOVA generate information on the instructional mode main effect (independent of locus of control), a locus of control main effect (independent of instructional method), and the

		Locus of Control		Main Effect Treatment Marginal
		External	Internal	
Treatment	Lecture	Cell Data External/Lecture Students	Cell Data Internal/Lecture Students	Total Lecture Data
Treatment	CAI	Cell Data External/CAI Students	Cell Data Internal/CAI Students	Total CAI Data
Main Effect LOC Marginal		Total External LOC Data	Total Internal LOC Data	Sample Data

Figure 1. Research Design Matrix

effects due to a combination of instructional method and locus of control. It is this last effect, the interaction, which is of primary interest.

An analysis of covariance was performed to adjust for students' prior ability and/or achievement history. Measures of prior ability consisted of 1) SAT math score; 2) ACT math score; 3) MSU math placement score; and 4) previous math course grade. Since these measures were external to the course involved in this experiment, permission to obtain and use this covariate data was requested of the Committee on the Release of Confidential Information. As students had signed a consent for the release of this information, the request was approved. The pertinent memoranda can be found in Appendix B.

Other data collected for possible use as covariates were student performance measures within the Math 108 course. These consisted of quiz, homework, and unit exam scores. Formal instruction time (time in lecture or at the CAI station) was also recorded. The students were also asked to keep track of their study time. Cronbach and Snow (1977) state:

> In few studies of PI was the time devoted to instruction and study controlled....This failure of experimental design (compounded by the failure to record time differences and adjust for them) is sufficient to account for the mixed results in the literature. (p. 178)

On-task time in the CAI method is consistantly and significantly less than the time spent in lecture. To account for the time compression effect of CAI and to control for differences in study times, these two data items were collected.

The design matrix for the two-way analysis of covariance is identical to that of the ANOVA (see Figure 1). The statistical models and analysis procedures are different to be sure. The particular format of the design matrix highlights the main effects as the marginals and the interactions as cell information.

Regression analysis is the preferred mode of evaluation and is performed in addition to the ANOVA and ANCOVA for this study. ANOVA treats independent measures as qualitative factors. Although LOC is a continuous scale, partitioning the scale into internal and external groups is little more than an artifact of the study. Regression analysis recognizes the continuity of the scale and treats the locus of control measure in a quantitative sense. The outcome of a regression analysis, single or multivariant, is an equation that can be used for predicting academic achievement. Generating regression equations for each treatment makes possible a differential assignment of students to particular treatments on the basis of their locus of control measure and other covariate data.

Detailed discussions of ANOVA, ANCOVA, and linear regression techniques can be found in most comprehensive texts on statistical analysis procedures (Hays, 1973). Complete descriptions of the analysis procedures used in this study are given by Nie, Hull, Jenkins, Steinberger, and Bent (1975).

Significance Level

In conjunction with the stated hypotheses and analysis procedures, mention of the decision rules in their acceptance or rejection is in order. The conventional significance level represented by $\alpha = .05$ was used (Hays, 1973). If the sample results fell among the top five percent of a normal distribution of all possible sample results given the null hypothesis (H_0) to be true, H_0 was rejected and the alternate hypothesis (H_A) was accepted. If the sample results are not among the highest five percent, then H_0 is accepted.

The discussion centers on the statistical significance of the experiment. It argues that the sample results are statistically significant if they fall beyond the five percent level. In other words, less than five percent of all similar samples show results at least this deviant from the expectation under the null hypothesis, if H_0 is actually true. Samples falling into this extreme region show significant departures from the expectation, if H_0 is indeed true, that doubt is cast upon the truth of the null hypothesis. Under these conditions H_0 is rejected while H_A is accepted. Hays (1973) defines statistical significance as:

> A sample result falling into the region of rejection is said to be statistically significant, or to depart significantly from the expectation under the hypothesis. (p. 337)

Reliability and Validity Concerns

Reliability has been defined as the "degree of consistency between two measures of the same thing" (Mehrens & Lehmann, 1973, p. 102). The reliability of a measurement or an experiment is therefore, an indication of replicating a given outcome on several subsequent and independent trials. There are three aspects of reliability crucial to this study: the locus of control instrument, the achievement measure, and the results of the study. The Intellectual Achievement Responsibility Questionnaire (Crandall et al., 1965) was selected as the locus of control instrument for three reasons: 1) its situation specific nature; 2) the lack of any substantiated interactions or correlations with race, sex, or anxiety; and 3) the separate subscales for acceptance for success and failure. The test-retest reliability represents a measure of stability, i.e., will students receive similar scores given the questionnaire a second time. For junior and senior high school students, the test-retest reliabilities for the I+, I-, and total I scales are .47, .69, and .65 respectively. Measures of the IAR's internal consistency have been reported as .60 for both the I+ and I- subscales for junior and senior high school students (Crandall, et al., 1965). There are no reported effects due to sex or race. These reliability coefficients are certainly acceptable and are comparable to most other locus of contol measures (Stipek & Wiesz, 1981).

IAR reliability indices obtained for the students participating in this study were comparable to those reported in the literature. KR-20 reliability indices for the Winter trial were .60, .55, and .64 for the I+, I-, and total I scales respectively. Indices for the Spring trial were .49, .35, and .55. A composite sample of both Winter and Spring trials produced KR-20 reliabilities of .56, .51, and .41.

The reliability of the achievement measures is presented in a later section, so any detailed discussion is deferred for the time being. However, reliability indices for the achievement measures were .79 and .71 for the Winter and Spring trials respectively.

One of the research questions initially posed was related to the reliability and generalizability of the experimental findings. The study consists of two separate trials. The first trial was conducted during the Winter 1983 term and the second during the Spring 1983 term. The procedures for each trial were identical as were the instructional materials. The lecturer presented the materials using the same lecture notes, textbook, and schedule for both trials. Every attempt was made to ensure consistency in the content and conduct of the experiment. The two trials were analyzed separately in order to gain insights into the consistency of the findings. After performing statistical t-tests on the trial data, a combined sample was analyzed to establish more stable and generalized results. The study was replicated using different samples to attest to the reliability and generalizability of the experimental results.

Validity has been defined as the "degree to which a test is capable of achieving certain aims" (Meherens & Lehmann, 1973, p. 124). In a sense, it is an assessment of whether one is actually measuring what is intended. The two issues concerning validity that arise in this study are validity of the achievement measure and validity of the IAR Questionnaire. The content validity of the achievement tests is judged to be acceptable. The course instructor prepared the examinations using the stated objectives as a guide and patterned the problems after textbook and homework examples. This author reviewed the test items and found them to reflect the skills and knowledge stated in the objectives.

The exams were also reviewed by the authors of the textbook. Hestenes (Note 1) considered the tests to be representative of the material. He thought both tests were very similar but the exam used in the Spring trial was slightly better. Hill (Note 2) concurred in that the test items adequately addressed the concepts being taught and that the exams properly weighted the ideas being presented. Both reviewers did comment on the absence of overt partial credit scoring because of the problem-solving nature of the items. They also noted that even though the tests were fairly representative of the subject matter, they did not relate well to the stated objectives.

The second area pertains to the construct validity of the IAR Questionnaire. This questionnaire was selected because of its situation specific nature and low correlations with other personological measures. The I-E Scale (Rotter, 1966), while having slightly higher values of internal consistency and test-retest reliability, has been criticized for having low construct validity, especially for minority groups (Gurin, et al., 1969). Factor analysis of the IAR Questionnaire resulted in two major factors which form the two subscales (Crandall, et al., 1965). The IAR Questionnaire, therefore, has the properties of being academically oriented and having little overlap with other possibly confounding personality attributes.

This author is aware, however, of the various sources of internal and external invalidity (Campbell & Stanley, 1963). These sources were minimized whenever possible. Detailed information concerning the intent of this investigation was minimized during the study. The study was presented simply as an effort to compare and contrast lecture with CAI. The amount of information pertaining to the locus of control aspect of the study acquired by the students is unknown. Everyone, however, received the same introductory remarks and relevant background information. Other sources of invalidity not strictly controlled include the amount of tutoring the students received. The amount of time spent studying outside of class was collected and used for analysis purposes but the quality of the study time was not assessed. Any impromptu revisions and/or increased emphasis of specific topics during the lecture is also unknown. Neither the author nor the lecturer were unbiased observers. The design of the materials and the controls used in the CAI presentation, however, paralleled the lecture as closely as possible.

Students participating in the study possessed different backgrounds and interests. Previous experience with computers, attitudes toward the CAI and lecture methods, attitude toward the lecturer, and college major were not measured. Their impact is minimized through the random assignment procedures. Previous performance and/or ability in mathematics was determined and incorporated into the analysis of covariance.

Another major concern is mortality--students dropping out of the study. To minimize the probability that students would drop out, the experiment was conducted toward the end of the academic quarters. Most students dropping the course had already done so. Several of the students opted to remain in the lecture section even though they were assigned to the CAI treatment. The impact these students had on the results is discussed in detail in the next chapter. No one actually dropped out of the experiment once it began.

Predictions

The research hypotheses have been stated in the standard null format. The literary review, however, provides some insight from which to make a few predictions. The intent of this study was to investigate the existence of an aptitude-treatment interaction between locus of control measures and instructional methodology. The basic difference between the two educational techniques is the method of delivering instruction. The CAI method is a highly structured, formal, student-machine interaction, while the lecture was more informal, often utilizing in-class tutors to assist small groups of students. These two treatments are not unlike those used by Janicki and Peterson (1981) with the CAI similar to the large group approach and the lecture comparable to the small group approach. These authors reported that students with pessimistic attitudes toward math and external levels of locus of control performed better in the large group method while students with positive attitudes and an internal orientation preferred the small group approach. Coupling these findings with the general consensus that CAI tends to be more beneficial for the less able students and externally oriented students typically have lower levels of academic achievement, an ordinal ATI should result, with external students performing better in the CAI method and internal students showing no significant difference in achievement on the basis of treatment. Such an interaction would indicate that CAI would be superior for all students if achievement were the only consideration. It would also indicate that internally oriented students would record higher levels of performance than the external students.

The covariate analysis should enlarge the observed ATI to some extent. It shouldn't change the nature of the outcome but simply make the slopes of the regression lines more divergent. The basis for this prediction rests with the time compression effect. Adjusting for an assumed reduction in formal instructional time for the CAI group, differences between regression line slopes should be increased. If prior knowledge is used as a covariate, the regression lines should become more convergent; external CAI students should become more comparable with external lecture students.

Furthermore, the dominant covariate measures will most likely be formal instruction time, previous math course grade, MSU math placement score, and a course test average (excluding the achievement measure used in this study). These measures are local scores indicative of a student's work at MSU. The other coursework related measures (quiz and homework scores, and study time) will probably be of little use due to an insensitivity to adequately measure differences between individuals. In other words, scores on these three measures will, in all likelihood, be equivalent. Standardized measures such as the SAT or ACT math scores will probably not be very important because of their reportedly low correlations with locus of control.

Procedures

Population and Sample

The population of interest in this study was all college students requiring or enrolled in the College Algebra mathematics course at Michigan State University. The population can be further defined as those students who have little or no experience with computers as a method for providing instruction. Moreover, the sample used for this experiment was drawn from the freshmen engineering class.

Students enrolled in the College Algebra (MTH 108) course during the Winter 1983 and Spring 1983 terms were the subpopulation of this greater population. Moreover, the students were ethnic minority freshmen engineering students registered in a section of the College Algebra course offered by the Department of Mathematics. The experiment was conducted using intact classes and therefore, results and recommendations are pertinent to classes rather than individuals. The course content was comparable to the other MTH 108 sections, although emphasis of various course concepts and/or procedures were not standardized across all sections. For the purposes of this study, the course was conducted in the same manner, using the same materials and lecturer for both trials.

The fact that the experimental subjects were minority students, predominantly Black, is not viewed as a limitation of the experimental results. The IAR Questionnaire does not appear susceptable to either racial or sexual differences, and, hence, lends credence to the generalizability of the findings.

Initially the numbers of students enrolled in the MTH 108 courses were 35 and 31 for the Winter and Spring terms respectively. Several students dropped out of the course prior to the beginning of the experiment. Natural attrition reduced the number of students completing the locus of control measure to 32 and 22. Due to various complications during the Spring quarter, the final sample size was reduced to 19. Two students did not complete the course, and one student was physically handicapped and received special instruction.

One week before the beginning of the experiment, the author went into the classroom and described the research project and requested student participation. All of the students in both trials agreed to participate in the research effort. The IAR Questionnaire, a consent form for the release of confidential information, and a survey form for recording external study time were handed out. Students kept the external time survey until the experiment was completed. Appendix C contains copies of these documents.

The IAR Questionnaires were analyzed and students were classified as internal or external, depending on the position of their IAR total score relative to the sample mean. This procedure is typically used in LOC research (Rotter, 1975). In this manner a bilevel qualitative stratification for LOC is created that permits study of the interaction between LOC and instructional treatments. Students in each LOC group were then randomly assigned to one of the treatment groups. Students selected for the CAI treatment were again informed of the differences between the instructional modes and asked if they wished to continue their participation. Students not electing to work in the CAI format remained in the lecture treatment and were not replaced by students originally selected to receive the lectures. Five students in the Winter sample and two in the Spring trial elected to remain in the lecture sections. Chapter IV presents the final distributions and a discussion of possible differential effects these seven students might have had on the results.

One of the limitations mentioned in Chapter I was that only one microcomputer station was available. Students agreeing to use the CAI system scheduled three one-hour sessions, one hour for each of the three CAI lessons. These students did not attend lecture although they were required to complete the homework assignments and take the quizzes. The appropriate quizzes were prepared in advance and administered by the author when the students reported to use the computer. The duration of the treatments was eight days (including a weekend). On the ninth day the achievement test was given and students returned their external study time surveys.

Treatment Description

The CAI delivery system and materials have been discussed in an earlier section. The flexibility afforded by the design of the system was not fully implemented for the purpose of this investigation. The instructional materials were not written for processing at different levels of difficulty. The CAI groups received the same courseware in the same sequence, at the same level of difficulty. The system is not able to perform branching within a particular lesson but it can accommodate branching between lessons. Due to time constraints and the fact that only three lessons were involved in the study, the lessons were presented in the same order for each student. The linear presentation, therefore, paralleled the lecture sequence and eliminated the "blackout ratio" problem that confounded many PI studies (Tobias, 1969). (Blackout ratios are a measure of instructional frames skipped relative to the total number of frames in a lesson.)

Students were allowed to skip around within any CAI lesson at their own discretion. Every student proceeded straight through the lessons and then skipped around as a means of review. The calculator features were also available though most students used their pocket calculators to solve numerical problems. As mentioned before, feedback was provided immediately after each item and a summary of the student's performance was given at the end of each lesson. Additionally, the random number generator was engaged so that students would not receive identical problems but parallel forms. All problems and questions required student input, thus making the CAI treatment highly active and engaging.

The lecture groups met in the mornings for 50 minutes every day. Classroom activities typically consisted of a 10-15 minute quiz and review, a 10-20 minute formal lecture, and 15-30 minutes of questions and problem-solving. As the experiment proceeded the amount of time spent in formal lecture declined as the time spent for questions and problem-solving increased. Initially the instructor posed questions and demonstrated their solutions. As the week progressed the formal lecture became intermixed with student questions until the entire session, except for the quiz, was spent on answering questions posed by the students. The day before the unit exam, 40 minutes were allocated for the review and problem-solving functions.

There were five days of lecture and one day of review before the unit exam. The lecture groups were, therefore, in class for six one-hour sessions while the CAI groups received the same material in three one-hour sittings. In-class tutors were also present in the lectures. Their function was to grade the quizzes, returning them within the hour, and to grade the homework. The CAI groups received their quizzes immediately before they signed onto the computer system. These quizzes were graded by the class instructor and returned within 24 hours. Their homework sets were graded by the tutors as had been the practice throughout the term. The tutors did not perform any one-to-one or small group tutoring during the class sessions. The extent of actual tutoring outside of class is not known.

A comparison of the two treatments shows the CAI method as more rigid and controlled. Even though active participation is mandatory, the technique was not particularly responsive to student queries. The lecture mode was not of the typical large group or TV models but of the small group, informal paradigm.

Instrumentation and Data Collection

The various measures used in this study are locus of control, the achievement test, and covariate data. The locus of control instrument used was the IAR Questionnaire and the reasons for its selection and administrative procedures have been previously discussed. The achievement measure is described in the next section.

The covariate variables fall into two categories: primary and secondary. The primary covariates are those which are expected to be important in the data analysis. The secondary covariates are also expected to affect the experimental results but to a lesser extent. The primary covariates are the formal instructional time, previous course grade, MSU math placement score, and course exam scores. The formal instruction time is the total amount of time in class (taken from attendance records) or the time logged into the CAI system (collected during CAI access procedures). The previous course grade and MSU math placement score were obtained from university records. The MTH 108 instructor administered five unit exams during the term. The last exam served as the achievement measure for this study. The four other exam scores were averaged to give an average course exam value. This data was obtained from the instructor at the conclusion of the academic quarter.

There were five secondary covariate data items: SAT and ACT math scores, MTH 108 quiz and homework grades, and study time. SAT and ACT scores were obtained from university records. Study time was collected from the surveys students completed and returned at the conclusion of the experiment. These forms requested study time before each lecture, after each lecture, and the time spent studying for the exam. The analysis procedures, however, aggregated these three times to form the total study time measure. The remaining data items were provided by the course instructor at the end of the term.

The quiz grade is a raw score representing the total number of points accumulated during the entire course (including the experimental period). Each quiz was usually two or three points in value. The rationale for using the raw score is that an average would not accurately reflect a student's overall approach to the material. Since each quiz did not carry much weight, students often took a very laissez-faire approach to this particular aspect of the course work. It was used as a motivational technique rather than a true assessment mechanism. The homework grade again covers the entire course and the tutors were responsible for correcting and grading the homework. Homework sets were scored on a 100 point basis and the homework grade used here is the average of all homework sets. Students not turning in an assignment received zero points which was averaged in. These two scores, therefore, are indicators of a student's mastery of the material. These scores and percentages were used in determining the overall course grade, so they were included as viable data items.

Achievement Measure

The achievement measure used for this study was a unit exam covering the material presented during the experimental trial. The final exam for the course was not used because the experiment was not conducted throughout the term. The subject matter covered by the achievement test represented roughly one-fifth the total term's course work. The unit exam was written by the course instructor and focused on the stated objectives. There were nine questions which required the student to completely work out the solution and construct a final answer. Each item was scored on a point basis and partial credit was given. A total of 100 points was possible and students had one hour to complete it.

The course instructor elected to prepare different exams for the two trials. The content of the exams, however, was similar as problems were generated directly from the objectives and patterned after textbook exercises. The test results were analyzed and means, standard deviations, and difficulty and discrimination indices were calculated. These two indices were computed using responses of students whose test scores were in the upper and lower 27% of the class. Copies of the exams, unit objectives, and test statistics can be found in Appendix D.

The reliability indices for the exams are the coefficient alpha developed by Cronbach (1951). The reason for using this particular index as opposed to the Kuder-Richardson KR-20 or KR-21 indices was due to the fact that test items were scored on a point basis rather than simply right or wrong. The reliabilities of these two tests are .79 (Winter) and .71 (Spring). Mehrens and Lehmann (1973) give a rule of thumb that reliability coefficients in excess of .65 are probably sufficient for making group decisions. Therefore, as classes, the achievement scores appear to have adequate reliability indices for making group but not individual decisions.

Additional Concerns

Since the samples consist of predominantly Black freshmen engineering students, the IAR Questionnaire was administered to a larger more heterogeneous population. Three sections of the engineering drawing course MMM 160 served as the comparison group. Sixty-two students filled out the IAR

Questionnaire, of which 57 provided valid data. The reason for conducting this survey was to demonstrate that the sample groups were statistically equivalent with regard to homogeneity and, therefore, representative of a much larger, more diverse group of students. The MMM 160 sections were composed of college level engineering students from all levels, freshmen to seniors, and they were predominantly white. Results of this survey and its relationship to the sample data are presented in the next chapter.

Summary

This chapter has presented the design aspects of the research effort. The design of the CAI delivery system and the courseware were discussed with respect to their potential. The actual implementation procedures were also presented. The CAI treatment did not take full advantage of the computer capabilities in order to eliminate factors that might obfuscate the research findings. Instructional materials were prepared and presented at the same difficulty level for all students. Branching within and between CAI lessons was not permitted. The lecture treatment was also described and the differences between the two treatments were highlighted.

The various assessment measures were also described along with their relevance to the data analysis procedures. Data analysis techniques consist of analysis of variance, analysis of covariance, and simple linear regression analysis. The dependent variable is the achievement score on a teacher made unit exam in the College Algebra course. Predictor measures are the three IAR scores, I+, I-, and their sum. Covariates are SAT and ACT math scores, previous math course grade, MSU math placement score, on-task and study times, course quiz, homework, and exam average grades.

This chapter also presented some anticipated results which were formulated from information in the literary review, the stated hypotheses, and the experimental design. The relative importance of the treatments and covariates is forwarded in which an ordinal interaction is expected. External students should benefit from the CAI treatment while internal students can effectively use either instructional system.

The chapter concludes by presenting a detailed discussion of the procedures employed in conducting the experiment. The temporal relationships, assignment procedures, and data sources were described to aid in future studies of this type. The next chapter presents the results of each experimental trial and the procedures used to combine the data to form a single sample.

CHAPTER IV

ANALYSIS OF THE DATA

Introduction

This chapter contains the results of the experiment. Results of the MMM 160 survey and the stratified random sampling are presented. Since there were two experimental trials, the issue of combining the data is addressed. The chapter then proceeds in the logical sequence of: 1) presenting a research hypothesis; 2) transformation of the hypothesis into a statistically testable form; 3) presentation of the appropriate tables; 4) graphical displays of the results if relevant; and 5) a statement of whether the hypothesis was accepted or rejected. This pattern is applied for each of the research hypotheses.

Sample Representativeness

This section addresses two major concerns: 1) whether samples consisting of predominantly Black students limit the generalizability of the study, and 2) whether the dichotomization of the locus of control measure is a valid research procedure or simply a means of creating a standard research design. The IAR Questionnaire was administered to three sections of the MMM 160 course with the permission of the course coordinator and the section instructors. Table 1 provides a comparison of the I+, I-, and I total scores for students in the two trials and the larger, more heterogeneous MMM 160 group. The only commonality shared by the experimental groups and the MMM 160 students is that most were enrolled in one of the engineering disciplines. The groups differed in specific engineering majors, college level, and racial backgrounds. KR-20 reliability indices for the three IAR scores were .45, .45, and .51 which are comparable to those of the experimental groups.

To test the equivalence of the IAR measures, a one-way analysis of variance was performed under the assumption that all mean scores were equal. The results of this analysis are also presented in Table 1. The significance level chosen for this study was $\alpha = .05$, so both the I- and I total scores are significantly different. Moreover, post-hoc comparisons indicate that the two experimental groups are equivalent but statistically different from the MMM 160 group on these scales. These results indicate that while all three groups are similar in their attribution of success to personal factors, the MMM 160 students are more external in their attribution of failure. It appears that the I-subscale differs sufficiently to cause the overall IAR scores to be significantly different. Indeed, the minority samples have consistently higher, more internal scores on all scales than the larger group. Speculations for, and implications of this trend are discussed in more detail in the next chapter.

Table 1

Analysis of Variance--IAR Scores
Winter, Spring, and MMM 160 Groups

Group	Number of Cases	Mean	Standard Deviation	Range	F	F Prob.
			IAR I+ Subscore			
Winter	32	14.13	2.04	10-17		
Spring	22	13.77	2.00	10-17	1.097	.3375
MMM 160	57	13.49	1.87	8-17		
			IAR I- Subscore			
Winter	32	13.41	2.20	7-16		
Spring	22	13.05	1.99	8-16	3.344	.0390*
MMM 160	57	12.28	2.00	7-17		
			IAR I Total Score			
Winter	32	27.53	3.30	19-33		
Spring	22	26.83	3.20	21-33	3.460	.0350*
MMM 160	57	25.77	2.94	19-31		

* Significant at the $\alpha = .05$ level.

In defense of dividing students into internal and external groups, Rotter (1975) argues that it isn't a good versus bad dichotomy and states that "there is absolutely no justification for thinking in terms of a typology" (p. 62). Such a separation, however, is customary in locus of control research. Although a separation of the LOC was used, only two levels were created and the eventual regression analysis ignores such blocking procedures. Indeed, the intent of this study is to develop regression equations which treat the locus of control measure in a quantitative rather than qualitative manner.

Treatment Assignments

Students participating in the experimental groups were classified as internal if their IAR total score exceeded the sample mean or external if their score was below the sample mean. Once internal and external groups were formed, students were randomly assigned to one of the treatment groups. Students whose scores were at the IAR mean were randomly assigned as internal or external prior to treatment assignments. Table 1 gives data for the IAR total score. The Spring term trial had 22 students complete the questionnaire. Three students, however, were excluded from the final sample even though their IAR scores were used in treatment assignments. Table 2 provides the final distribution for each trial and for a combined sample.

Table 2

Treatment Assignments
Final Distribution

	Winter			Spring			Composite		
	Ext.	Int.	Total	Ext.	Int.	Total	Ext.	Int.	Total
Treatment									
Lecture	10	11	21	4	6	10	14	17	31
CAI	7	4	11	4	5	9	11	9	20
Total	17	15	32	8	11	19	25	26	51

Combining Samples

Since two trials of the study were conducted, an aggregation of the data is desirable to improve the statistical analysis procedures. The one-way ANOVA indicated that the two trials were equivalent on each of the IAR scales. The trials are considered independent samples and hence a t-test of the dependent variable sample means provides the basis for combining the data. (One student repeating the course Spring term was eliminated from the study.) Table 3 presents the t-test results for the IAR scales and the achievement measure. The F-ratio listed is an indicator of the equivalence of variances. The two-tailed probabilities are all in excess of the conventional significance level of $\alpha = .05$. The two samples are, therefore, considered to have equal variances on each of these measures.

The t-test for the achievement measure shows that the two samples have equivalent variances ($F = 1.16$, $P = .689$) but that the pooled variance estimate was computed as having a 2-tailed probability of $P = .002$, clearly less than the chosen significance level. The sample means cannot be considered as statistically equal. One interpretation was that the Spring term exam was more difficult than the Winter term exam. It may also be indicative of the differential in entry level skills between the two samples. The math courses for engineering students are in a hierarchical sequence, so most of the Spring term students began their MSU college math sequence one level lower than the Winter

Table 3

Sample Combination
t-test Summary Statistics
IAR and Achievement Scores

Trial	Number of Cases	Mean	Std. Dev.	Std. Error	F Value	2-Tail Prob.	Pooled Variance Est T Value	Pooled Variance Est df	Pooled Variance Est 2-Tail Prob.
IAR I+ Score									
Winter	32	14.13	2.04	0.36	1.11	0.842	0.21	49	0.831
Spring	19	14.00	1.94	0.45					
IAR I- Score									
Winter	32	13.41	2.20	0.39	1.07	0.896	0.56	49	0.576
Spring	19	13.05	2.12	0.49					
IAR Total Score									
Winter	32	27.53	3.30	0.58	1.04	0.959	0.50	49	0.617
Spring	19	27.05	3.24	0.74					
Achievement Measure									
Winter	32	80.53	15.76	2.79	1.16	0.689	3.30	49	0.002*
Spring	19	65.00	17.01	3.90					

* Significant at the $\alpha = .05$ level.

term students. The subsequent analyses, therefore, will be presented on a trial basis. However, at the risk of committing a Type I error (accepting an equivalence of sample means when they are indeed unequal), analyses for a combined sample will also be presented.

Analysis of Variance

Analysis of variance provided the statistical means of addressing the first three research hypotheses. All data analyses were performed by the Statistical Package for the Social Sciences (SPSS Version 8.3) available through the MSU central computing facility. Tables 4, 6, and 8 provide cell means, standard deviations, and marginals for each trial and the composite sample according to the design matrix shown in Figure 1. Tables 5, 7, and 9 present the results of the ANOVA procedure. The remainder of this section presents statistical results for each of the research hypotheses.

1. There will be no difference in the mean achievement scores for students in the traditional lecture and computer-assisted instructional treatment groups.

If μ_{LEC} and μ_{CAI} represent the mean achievement scores for the lecture and CAI treatment groups respectively, then the null and alternate hypotheses can be written as the following.

$$H_0: \mu_{LEC} = \mu_{CAI}$$

$$H_A: \mu_{LEC} \neq \mu_{CAI}$$

Table 4

Design Matrix, Achievement
Winter 1983 Trial

Winter 1983 Achievement		Locus of Control External	Internal	LOC Marginal
Lecture	$\bar{x}$	85.10	77.73	81.24
	σ	13.52	21.94	18.36
	n	10	11	21
CAI	$\bar{x}$	82.14	74.00	79.18
	σ	6.18	13.29	9.63
	n	7	4	11
Treatment Marginal	$\bar{x}$	83.88	76.73	80.53
	σ	10.95	19.61	15.76
	n	17	15	32

Table 5

ANOVA Results, Achievement
Winter 1983 Trial

Source of Variation	Sum of Squares	df	Mean Square	F	Sig. of F P
Inst. Mode	75.743	1	75.743	.294	.592
LOC	452.491	1	452.491	1.756	.196
2-Way Interaction	1.016	1	1.016	.004	.950
Residual	7215.939	28	257.712		
Total	7699.969	31	248.386		

Table 6

Design Matrix, Achievement
Spring 1983 Trial

Spring 1983 Achievement		Locus of Control: External	Internal	LOC Marginal
Lecture	$\bar{x}$	73.75	69.50	71.20
	σ	19.16	16.38	16.62
	n	4	6	10
CAI	$\bar{x}$	56.00	59.80	58.11
	σ	22.46	9.55	15.46
	n	4	5	9
Treatment Marginal	$\bar{x}$	64.89	65.09	65.00
	σ	21.53	14.01	17.01
	n	8	11	19

Table 7

ANOVA Results, Achievement
Spring 1983 Trial

Source of Variation	Sum of Squares	df	Mean Square	F	Sig. of F P
Inst. Mode	811.962	1	811.962	2.819	.114
LOC	.667	1	.667	.002	.962
2-Way Interaction	74.772	1	74.772	.260	.618
Residual	4321.050	15	288.070		
Total	5208.000	18	289.333		

Table 8

Design Matrix, Achievement
Composite Sample

Composite Sample Achievement		Locus of Control: External	Internal	LOC Marginal
	$\bar{x}$	81.86	74.82	78.00
Lecture	σ	15.48	20.03	18.18
	n	14	17	31
	$\bar{x}$	72.64	66.11	69.70
CAI	σ	18.66	12.96	16.28
	n	11	9	20
	$\bar{x}$	77.80	71.81	74.75
Treatment Marginal	σ	17.22	18.12	17.77
	n	25	26	51

Table 9

ANOVA Results, Achievement
Composite Sample

Source of Variation	Sum of Squares	df	Mean Square	F	Sig. of F P
Inst. Mode	969.641	1	969.641	3.175	.081
LOC	589.803	1	589.641	1.931	.171
2-Way Interaction	.778	1	.778	.003	.960
Residual	14355.619	47	305.439		
Total	15783.686	50	315.674		

With reference to the design matrix, this hypothesis compares the treatment marginal means. The entries in Tables 5, 7, and 9 under "Inst. Mode" clearly indicate that the null hypothesis cannot be rejected for either trial or composite samples. The respective significance levels of the F-ratios are .592, .114, and .081, each in excess of the $\alpha =$ .05 level. Therefore, the null hypothesis is accepted; there is no difference in achievement between groups on the basis of instructional methodology.

2. There will be no difference in the mean achievement scores for students classified as internally or externally oriented on the basis of the total IAR score.

Using μ_{INT} and μ_{EXT} as representative of the mean achievement scores for the internal and external locus of control groups, the null and alternate hypotheses become:

$$H_O: \mu_{INT} = \mu_{EXT}$$

$$H_A: \mu_{INT} \neq \mu_{EXT}$$

This hypothesis tests the design matrix LOC marginals. The ANOVA table entries under "LOC" indicate that the null hypothesis must be accepted in all cases. The probabilities of obtaining the F-ratios are .196, .962, and .171 which are again in excess of the chosen significance level. Therefore, the null hypothesis is accepted and locus of control classifications do not affect achievement.

3. There will be no achievement interactions between instructional treatments and locus of control classifications; all students will perform equally well regardless of instructional method or locus of control orientation.

This hypothesis represents the ATI which this study was designed to investigate. Using $\gamma_{INSTMODE,LOC}$ to represent the interaction between instructional methods and locus of control classifications, the null and alternate hypotheses become:

$$H_0: \gamma_{INSTMODE,LOC} = 0$$

$$H_A: \gamma_{INSTMODE,LOC} \neq 0$$

The pertinent F-ratios are listed as the "2-Way Interaction" entries in the tables. In all three cases the significance levels of the F-ratios (Winter, .950; Spring, .618; Composite, .960) are substantially higher than the level for rejection of the null hypothesis. The null hypothesis must be accepted as true in all cases. Hence, in terms of achievement, there is no interaction between one method of instruction and a particular locus of control orientation; no ATI between these factors exists.

Acceptance of the null hypothesis for all three of these research questions indicates an across the board equivalence of these two instructional methods for all students regardless of their IAR total score. The trend, however, is for lecture to produce slightly higher, albeit not statistically significant, achievement scores. There is also a trend for externally oriented students to have higher scores than their internal counterparts. Figure 2 presents a graphical display of these trends. The treatment lines shown are not the results of regression analysis but simply

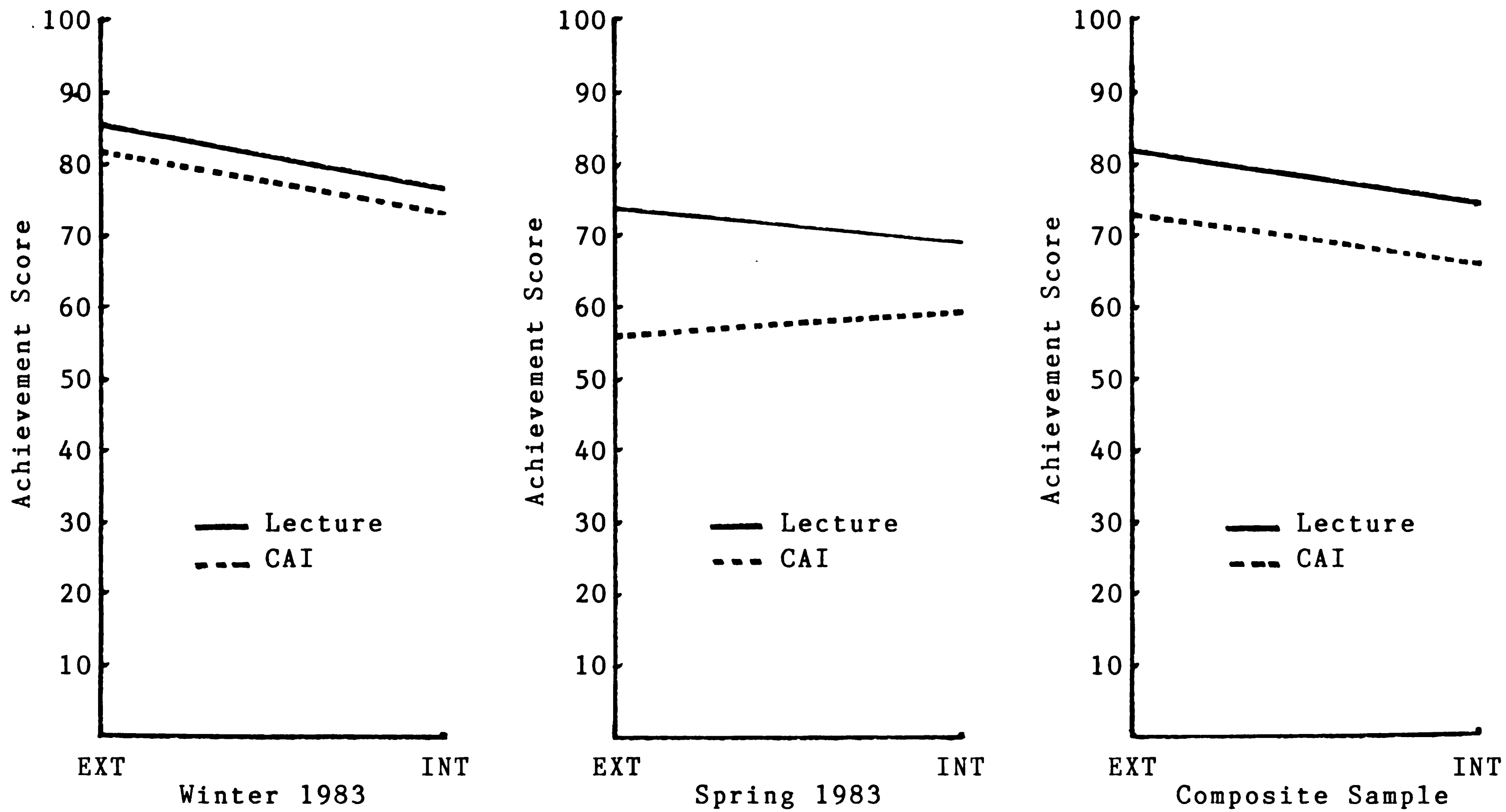

Figure 2

Achievement Means by Design Matrix Cell
Winter, Spring, and Composite Groups

connect cell means. The parallel nature of the treatment lines is indicative of no interaction effects--either ordinal or disordinal. Further discussion and interpretation of these decisions are presented in Chapter V.

Analysis of Covariance

The previous chapter presented the rationale for selecting covariates. Research studies suggest that prior knowledge, ability, and on-task time have significant influence on experimental results, especially in PI or CAI methodologies. An analysis of covariance is typically performed to control for the influence of one or more concomitant measures. ANCOVA therefore, statistically equates the samples across specified covariate measures.

Tables 10 and 11 present the ANCOVA data for the primary and secondary covariates respectively. The SAT math score was omitted because only 12 subjects in the entire study had this measure. The ACT is the preferred entrance measure for MSU. The hypotheses that follow are applied to each covariate.

4. There will be no difference in the mean achievement scores for students in the traditional lecture and CAI treatments after covariate adjustments.

Using a slightly modified form of the previous notation, this hypothesis can be written as:

$$H_0: \mu_{LEC}^{COV} = \mu_{CAI}^{COV}$$

$$H_A: \mu_{LEC}^{COV} \neq \mu_{CAI}^{COV}$$

Table 10

Achievement ANCOVA Results
Primary Covariates
Winter, Spring, and Composite Groups

	Winter		Spring		Composite	
	F	P(F)	F	P(F)	F	P(F)
Formal Instructional Time						
Int. Time	2.288	.142	.280	.605	5.213	.027*
Inst. Mode	.396	.534	.151	.703	.231	.633
LOC	1.341	.257	.013	.912	1.920	.173
Interaction	.176	.678	.159	.696	.211	.648
Unit Test Average						
Test Average	12.428	.002*	7.706	.015*	30.932	.001*
Inst. Mode	.370	.548	.743	.403	1.680	.201
LOC	1.028	.320	.234	.636	.406	.527
Interaction	.006	.938	.029	.867	.002	.966
MSU Math Placement Score						
MSU Math	3.887	.059	.472	.503	8.318	.006*
Inst. Mode	.747	.395	2.893	.111	4.272	.044*
LOC	2.109	.158	.018	.896	2.486	.122
Interaction	.132	.719	.107	.748	.135	.715
Previous Math Course Grade						
Prev. Course	.411	.528	15.265	.002*	8.807	.005*
Inst. Mode	.064	.802	.863	.370	1.079	.305
LOC	1.061	.313	.409	.534	.494	.486
Interaction	.024	.878	.242	.631	.013	.910

* Significant at the $\alpha = .05$ level.

Table 11

Achievement ANCOVA Results
Secondary Covariates
Winter, Spring, and Composite Groups

	Winter		Spring		Composite	
	F	P(F)	F	P(F)	F	P(F)
Study Time						
Study Time	.211	.649	.124	.730	.250	.617
Inst. Mode	.368	.549	2.109	.169	3.336	.074
LOC	1.735	.199	.004	.951	1.867	.178
Interaction	.003	.955	.137	.717	.014	.908
Quiz Average						
Quiz Average	1.298	.264	1.216	.289	4.795	.034*
Inst. Mode	.211	.649	1.771	.205	2.138	.150
LOC	1.056	.313	.018	.895	1.357	.250
Interaction	.008	.929	.198	.663	.039	.844
Home Work Grade						
Home Work	7.814	.009*	1.361	.263	7.148	.010*
Inst. Mode	.018	.893	2.400	.144	2.283	.138
LOC	1.129	.297	.000	.995	1.621	.209
Interaction	.232	.634	.140	.714	.069	.794
ACT Math Score						
ACT Math	.533	.472	2.395	.148	5.959	.019*
Inst. Mode	.076	.785	3.307	.094	2.649	.111
LOC	1.471	.237	.218	.649	2.201	.146
Interaction	.048	.828	.008	.930	.020	.888

* Significant at the $\alpha = .05$ level.

Inspection of the ANCOVA tables shows only one significant main effect for instructional mode. The composite sample produced a F = 4.272 with a probability of P = .044 when the primary covariate of MSU math placement score is controlled. In this lone case can the null hypothesis be rejected; there is a difference in achievement means for the lecture and CAI instructional methods when MSU math placement score is controlled.

Although non-significant, controlling for study time produced a F = 3.336 (P = .074) for the composite group. The probability is within .024 of the rejection region. At the risk of committing a Type II error (accepting H_0 when it is false), it was decided to accept the null hypothesis in this case. The decision to accept the null hypothesis that $\mu_{LEC}^{STUDY} = \mu_{CAI}^{STUDY}$ was based on the fact that the probability was not in the region of rejection and the covariate itself was not significant at the $\alpha = .05$ level. It is interesting to note the influence of this particular covariate in light of the criticism made by Cronbach and Snow (1977) regarding formal instructional and study times.

As a matter of fact, these are the only covariates that actually reduced the ANOVA instructional mode probabilities in the composite sample. All of the other covariates tend to strengthen the equivalence of instructional methods. Even if the alternate hypothesis was accepted for the study time covariate, two significant main effects out of the 24 possible is no better than chance alone.

5. There will be no difference in the mean achievement scores for the internally or externally oriented students after covariate adjustments.

Using a modified notation, the pertinent hypotheses are written as:

$$H_0: \mu_{INT}^{COV} = \mu_{EXT}^{COV}$$

$$H_A: \mu_{INT}^{COV} \neq \mu_{EXT}^{COV}$$

Referring to Tables 10 and 11, one can see that none of the F-ratios for LOC are significant. The only two covariates lowering the ANOVA probabilities were the MSU math placement and ACT math scores. The MSU math placement score with P = .122 and the ACT math score with P = .146 are less than the P = .171 of the unadjusted ANOVA computations. However, these probabilities are well within the region where the null hypothesis must be accepted. Therefore, the null hypothesis is accepted for all of the covariates.

6. There will be no achievement interactions between instructional treatments and locus of control classifications after covariate adjustments.

As mathematical statements, the hypotheses are cast as follows.

$$H_0: \gamma_{INSTMODE,LOC}^{COV} = 0$$

$$H_A: \gamma_{INSTMODE,LOC}^{COV} \neq 0$$

The values for the interaction effects are given in Tables 10 and 11 under the "2-Way Interaction" entry. The analysis indicates, unequivocally, that there is absolutely no interaction between instructional treatment and locus of control classifications. Therefore, the null hypothesis is again accepted for all covariate factors in all cases.

Regression Analysis

As the previous forms of analysis have indicated, there appears to be no significant main or interaction effects between the variables in this study. The previous two forms of the analysis do not provide a clear picture of the relationship between the variables, nor did they permit an investigation of the two locus of control subscales. Using the somewhat arbitrary division of the total IAR score to form internal and external groups does not fully utilize the quantitative nature of the locus of control measure. Blocking on the LOC scale facilitates the ANOVA and ANCOVA types of analyses, but the main objective of ATI research is to generate regression equations useful for prediction purposes. This section will therefore, develop regression equations for each trial and the composite group using the I+, I-, and total IAR scores as predictors.

7. There will be no difference in the slopes of the regression lines (academic achievement as a function of locus of control measures) for the lecture and CAI treatments.

Linear regression analysis was performed for each treatment and the three IAR scores. The regression coefficients are displayed in Table 12. Since the regression involves just one predictor (IAR score) and one criterion measure (achievement), there are two regression variables--

Table 12

Linear Regression Coefficients
Achievement Versus Locus of Control Scales
Winter, Spring, and Composite Groups

	Winter		Spring		Composite	
	Slope	Const.	Slope	Const.	Slope	Const.
I+ Subscale						
Lecture	-1.87	107.40	.59	63.01	-1.15	94.04
CAI	-1.16	95.86	1.62	35.20	.42	63.69
I- Subscale						
Lecture	.28	77.46	-.64	79.47	.33	73.59
CAI	.16	77.08	-1.92	83.48	-.77	79.85
IAR Total Score						
Lecture	-.73	101.41	-.13	74.60	-.33	87.01
CAI	-.27	86.49	-.08	60.30	-.18	74.59

Note. Equations of the form: Achievement = Slope * IAR + Const.

the slope of the line and where it crosses the vertical axis. These are listed as "Slope" and "Const." respectively.

The ANOVA and ANCOVA analyses indicated that ATI's are non-existant if the IAR total score is used as the independent, predictor measure. Indeed, the slopes of the regression lines under the "IAR Total Score" heading are all negative and roughly equal; the lines are almost parallel. Figure 2 gave preliminary indications of the parallel nature of the IAR total score regression lines. Linear regression analysis using the I+ and I- scores as predictors produced interesting results. The regression lines for each treatment are quite similar for each trial separately. Comparing the lines between terms shows a reversal from Winter to Spring. The Winter sample is described by descending lines for the I+ scale and ascending lines for the I- scale. Just the opposite is true for the Spring term sample. The composite sample has the most interesting combination. For both of the subscales the regression slopes are of opposite sign. One line is rising while the other is falling. Figures 3 and 4 graphically show the regression lines. If I+ is used as the predictor, the lines indicate an ordinal interaction (non-parallel, non-crossing). The I- predictions, however, are indicative of a disordinal interaction (regression lines cross within the range of the predictor measure). The fact that the lecture line is falling in the I+ figure and rising in the I- graph while the reverse is

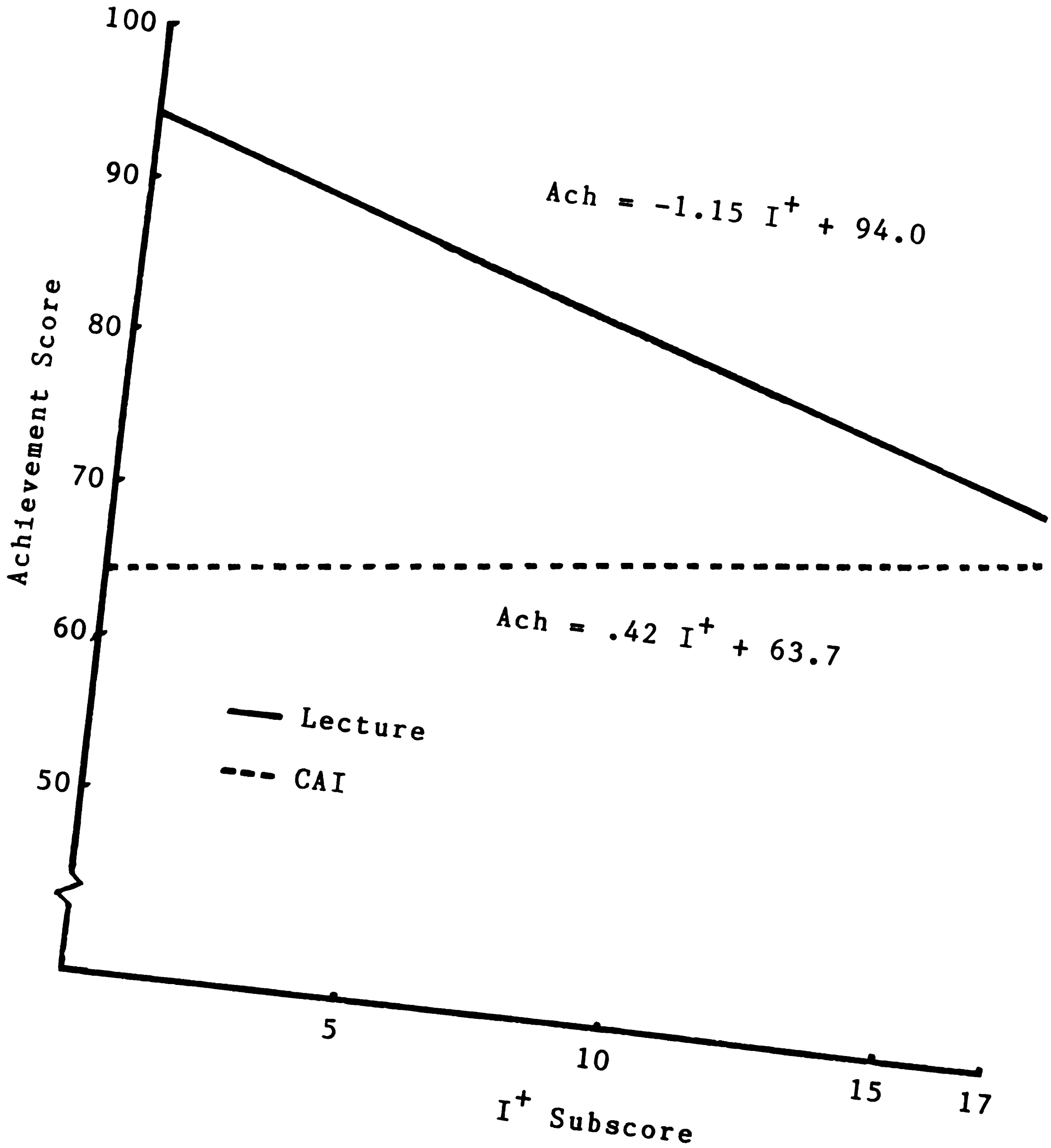

Figure 3

Regression Lines for I^+ Subscale
Composite Sample

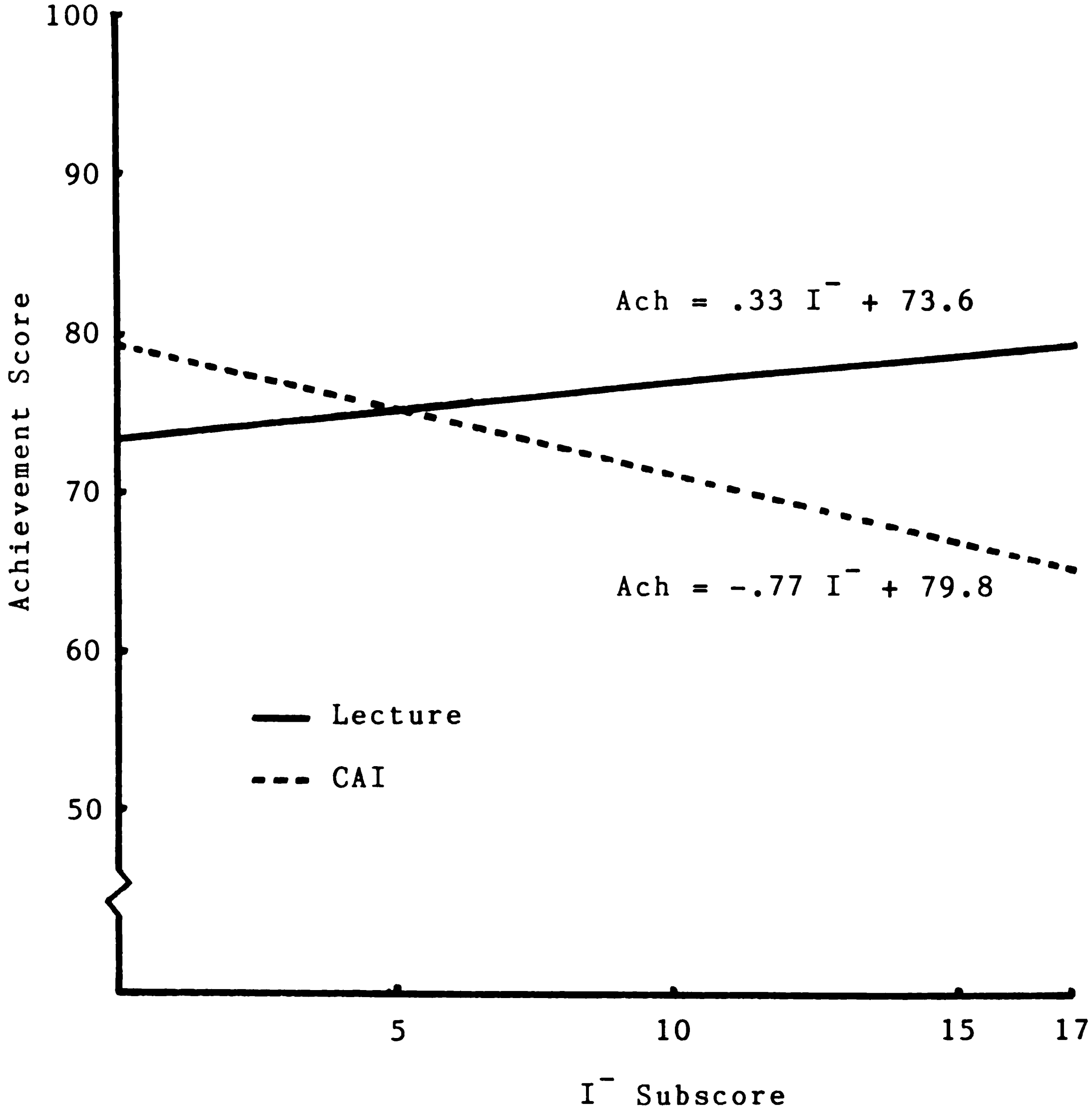

Figure 4

Regression Lines for I^- Subscale
Composite Sample

true for the CAI lines explains the reason for nearly parallel lines for the IAR total score.

Figure 3 indicates that lecture students scoring low on the I+ scale tend to gain higher scores than their CAI counterparts. Since the regression lines cross at I+ = 19.3 which is outside the range of the I+ scale, students scoring high on this scale showed no apparent achievement differential due to treatments. The opposite tends to hold using the I- scores as the independent measure. Students scoring higher on the I- scale seem to benefit from the lecture while all low scoring students perform equally well in either treatment.

Whether these trends are indeed statistically significant effects is determined by a test of parallelism. The following discussion is patterned after a procedure presented by Johnson and Jackson (1959). A complete formulation of these results is found in Appendix E. The calculations were performed for the I+ and I- scales on the composite sample data since these were the only two cases where regression slopes had opposite signs.

The linear regression equations for each treatment can be written as:

$$\hat{Z} = A_1 + B_1X \qquad \text{(Lecture)}$$

and

$$\hat{Z} = A_2 + B_2X \qquad \text{(CAI)}$$

where $\hat{Z}$ represents the predicted achievement score and X is the locus of control measure of interest. The A's and B's are the regression parameters presented earlier. To test whether the regression lines are parallel the null and alternate hypotheses can be written as:

$$H_0: \ (A_1 - A_2) + (B_1 - B_2)X = 0$$

$$H_A: \ (A_1 - A_2) + (B_1 - B_2)X \neq 0$$

The procedure, in outline form, is to demonstrate equivalence of treatment variances with respect to the $\hat{Z}$ distributions, test whether $B_1 = B_2$, and then see if $A_1 = A_2$. The F-ratios associated with these three steps for each of the I+ and I- calculations are presented in Table 13. None of the F-ratios are significant at the $\alpha = .05$ level. It is apparent that the regression lines are statistically parallel. The trends indicated in Figures 3 and 4 are not statistically significant. The quantitative nature of the regression analyses confirm the ANOVA and ANCOVA results that the treatment groups are equivalent for all levels of locus of control--subscales as well as the total score.

These analyses give insufficient grounds for rejecting the null hypothesis for the total IAR score or the two subscales; the regression slopes are equal. Indeed, since $A_1 = A_2$ the lines themselves can be considered statistically equivalent.

Table 13

Test of Parallelism
I+ and I- Regression Equations
Composite Sample

Predictor		$\hat{\sigma}_z$	F	Constant	F	Slope	F
I+	Lecture	18.34	1.21	94.0	2.91	-1.15	12.47
	CAI	16.70		63.7		.42	
I-	Lecture	18.47	1.23	73.6	2.72	.33	27.93
	CAI	16.62		79.8		-.77	

Note. F-ratios for significance are 1.94, 4.04, and 252.

Johnson-Neyman Procedure

The last issue centers on the hypothesis:

8. There will be no extreme locus of control conditions where a differential application of instructional methodology is warranted based on significant differences in achievement scores.

The equivalence of regression equations for all of the IAR scales precludes the need for conducting any analysis designed to resolve this hypothesis. The Johnson-Neyman procedure is one such technique. The lack of any significant ATI forces the decision to accept the null hypothesis that no region exists whereby one treatment is preferred on a statistical basis. In view of the acceptance of the equivalence of the treatment regression lines for both I+ and I- as predictors, the present null hypothesis must be accepted; no extreme regions of the locus of control measures predict significantly different achievement levels between the two treatments.

In view of the decision to accept the null hypothesis, a presentation of the Johnson-Neyman procedure is inappropriate at this point. This procedure is used to determine regions of statistical significance in the event that significant interactions occur. For those readers interested in the concept and underlying philosophy of this procedure, Appendix E contains a discussion and the detailed mathematical calculations of the technique as it applies to the I+ and I- composite data.

Stability Across Samples

The results of this study are consistent for the two trials. The fact that no significant differences in main or interaction effects with and without covariate adjustments occurred for either the Winter or Spring samples emphasizes the acceptance of every null hypothesis.

The regression equations do differ for the two separate trials. Table 12 presents the parameters for the linear regression lines. The slopes for the Winter and Spring trials are of opposite signs on the I+ and I- subscales. The I+ scale has negative slopes for the Winter trial but positive slopes for the Spring sample. The opposite trend occurs in the I- scale. The slopes for the two treatments within each of the samples, however, are the same. Moreover, the slopes of the treatment lines using the IAR total score as the independent variable have the same sign for both trials. None of these trends, unfortunately, have any statistical significance.

The question of whether those few individuals selected for the CAI treatment but electing to remain in lecture influenced the outcome of the study was raised in the previous chapter. Table 14 presents the mean achievement scores of those students who elected to remain in the lecture. As much as can be expected, the division is an even split between external and internal students; these students were not all external or internal in their locus of control classification. Their achievement scores paralleled those of the entire groups. Externals scored higher than internals in the Winter and composite samples (see Tables 4 and 8) while the internal student out performed the external student in the Spring trial (see Table 6). Assuming these students had participated in the CAI treatment and that they received the same achievement scores, the net effect would have been to improve the lecture group performance while reducing the CAI scores (Winter) or leaving them relatively unchanged (Spring and composite). The number of students involved and the parallel trends with the full sample indicate that, if these few students had worked with the CAI treatment rather than the lecture, the results would strengthen the argument for lecture superiority over CAI. The results would not alter the locus of control factor nor the interaction effects.

Table 14

Mean Achievement Scores
Students Selected for CAI
Electing Lecture Method

	External	Internal	Total
		Winter Trial	
$\bar{x}$	92.5	56.0	70.6
n	2	3	5
		Spring Trial	
$\bar{x}$	54.0	63.0	58.5
n	1	1	2
		Composite Sample	
$\bar{x}$	79.3	57.8	67.1
n	3	4	7

The overall absence of any statistically significant findings within both trials and the composite sample lend credence to the stability of the research results. The lone alternate hypothesis that was accepted occurred in the composite sample ANCOVA with the MSU math placement score as the covariate. There was a significant difference between instructional treatments. Any adjustments made for those seven students remaining in the lecture mode would only have strengthened lecture superiority over CAI.

Summary

This chapter has provided the empirical results of the study. The four analysis procedures of ANOVA, ANCOVA, linear regression, and an abbreviated application of the Johnson-Neyman procedure were presented. The data was presented for each trial separately as well as in composite form. The reason for the separate sample analysis is based on a statistically significant difference in achievement scores between the two trials. The analysis of variance yielded no statistically significant difference in instructional treatments or locus of control classifications for either trial or for the composite sample. Interaction effects were also non-existent.

The analyses of covariance were conducted using eight different covariates: four primary and four secondary. The SAT score was dropped due to large numbers of students lacking this measure. Of the 24 ANCOVA calculations, only one main effect F-ratio was in the region of significance. Instructional mode constituted a significant main effect for the composite sample when the MSU math placement score was controlled. The only other F-ratio to even approach significance was for the study time covariate analysis in the composite sample. Here the instructional mode main effect fell short of reaching significance, thus the null hypothesis of no significant main effect was accepted. There were no locus of control or interaction F-ratios that approached significance for either trial or for the composite sample.

Linear regression analysis in which the IAR total score served as the predictor variable produced practically parallel lines with lecture superior to CAI. The ANOVA results showed, however, that the differences were not statistically significant. Predictions based on the I+ and I- subscores revealed interesting trends. Graphs of the composite sample regression data gave the appearance of an ordinal interaction for the I+ scale and a disordinal interaction for the I- scale. Even though the regression lines using the I+ and I- scores as the independent predictors presented the prospect of interesting interactions, the statistical results indicated that the lines were parallel and, therefore, interaction effects were non-existent.

The analysis concluded with a very brief discussion of the Johnson-Neyman procedure for determining regions of significance. Even though the Johnson-Neyman procedure is unwarranted for the data obtained in this study, this author considers the presentation of the method beneficial and of service to those readers interested in ATI research. Appendix E presents a more comprehensive description of the procedure along with mathematical computations using the I+ and I- composite data. This technique was included, despite the non-significant interactions, for illustrative purposes. Many ATI studies do not fully develop the analysis procedures to the point of obtaining regression equations and very few actually identify regions of significance when interactions are found.

The final section speculated on the possible impact of those students selected as part of the CAI treatment but opting to remain in lecture. Their achievement scores paralleled those of the larger groups, and simply shifting them from the lecture group to the CAI group would have strengthen the trend for lecture to be a superior, though not significantly, method of instruction. Such a shift would not have affected the locus of control or interaction results.

The overall analysis indicated that the two instructional treatments were equivalent, the two locus of control groups were equivalent, and that no ATI's existed. These conclusions apply for both trials and the composite sample. These results were consistent across trials and inclusion of covariates had little impact on the main or interaction effects. The single exception, however, is within that expected by chance alone. Regression analysis, which treated locus of control in a quantitative rather than qualitative sense, also showed an equivalence of treatments. Regression analysis revealed no significant dependency of achievement on the I+ or I- scales.

There are several issues pertinent to these findings which increase the risk of committing Type II errors. Results using the composite sample, although consistent with the separate Winter and Spring trial analyses, lacks statistical power due to a combination of different achievement measures. These findings are all the more tentative since the two exams had statistically different means. The Winter trial and the composite samples suffer from unbalanced cell sizes. Even though each cell in the design matrix is filled, the cell sizes are not proportional. The seven students who remained in the lecture contributed to this situation thereby reducing the power of the analysis procedures. Finally, the reliability indices for the IAR Questionnaire are not sufficiently high to make group decisions. The low reliability indices for the independent variable does not provide for as robust a study as desired. These are three major factors which might explain why no significant differences were found.

CHAPTER V

SUMMARY AND CONCLUSIONS

Introduction

This final chapter presents an in depth discussion of the research results, the degree of agreement with the stated predictions, and implications for continued research. The approach will be to first review the rationale for conducting the study and then to proceed with a discussion of the original research questions. This chapter is intended to aggregate the literature, the design and methodology of this study, and the experimental findings. The chapter concludes with suggestions for future research and personal reflections on this research effort.

Overview of the Study

The influence of computers, and more recently microcomputers, for direct instructional purposes presents instructors and administrators with a myriad of questions and decisions. The foremost question may center on the effectiveness of computer based instruction. A second concern is the cost, while a third question may focus on procedures for the efficient utilization of limited computer resources. This study investigated whether an aptitude-treatment interaction between student type, as measured by locus of control, and instructional methodology existed. The effective and efficient utilization of educational materials and resources requires knowledge on how to do so. The underlying premise of this work was that knowledge of an interaction between student locus of control and the educational methods of lecture and computer-assisted instruction might permit the pairing of students with treatments so as to optimize learning as well as management of often scarce resources.

Computer-assisted instruction has proven efficient in the reduction of direct instructional time. While the results show no detriment to achievement, scores still fall in a normal distribution--some students do extremely well, others do very poorly. The same applies for most of the other instructional techniques. The problem remains one of identifying which student characteristics differentiate the low and high achievers. If a set of characteristics interacting with instructional methods, the so called aptitude-treatment interactions, could be found, then differential assignments of students to the appropriate treatment would be of benefit.

This study focused on determining the influence of student locus of control on achievement within the learning environments of lecture and computer-assisted instruction. The Intellectual Achievement Responsibility (IAR) Questionnaire was used to assess student locus of control. This questionnaire, specifically designed for academic settings, contains two separate subscales: responsibility for successes and responsibility for failures. Students were split into internal and external groups with the mean of the total IAR score as the dividing point. These two groups along with the two treatments composed a 2-by-2 completely crossed experimental design.

The materials were drawn from a two week segment in a College Algebra course. There was a maximum of six lectures compared to three one-hour scheduled CAI sessions. The achievement measure was a teacher made test covering the materials presented during the experiment. The CAI system and courseware were designed and written by this author. The lectures were conducted by one of his colleagues.

The experiment was performed during the Winter 1983 term with 32 students and again in the Spring 1983 quarter with 19 students. The subjects were predominantly Black, freshmen engineering students. A comparison group of mostly white students was given the IAR Questionnaire, thereby serving as an indicator for extrapolating the experimental results to a larger, more heterogeneous population.

Analysis techniques consisted of analysis of variance and covariance, linear regression analysis, and an illustrative application of the Johnson-Neyman procedure for determining regions of significance in ATI studies. The ANCOVA procedures investigated eight possible contributing factors. The four primary covariates of instructional time, test averages, MSU math placement score, and previous course grade were predicted to be principle factors reflective of prior levels of achievement and ability. The four secondary covariates of study time, quiz averages, home work grade, and ACT math score were also considered as measures of ability but not contributory in a substantial way. The ANOVA and ANCOVA procedures were performed on each trial separately and on a combined sample.

The emphasis of ATI research is not to identify which instructional method is the best on average but to develop regression equations which can be used in predicting student performance and possibly assigning students to treatments on the basis of one or more independent measures. This study considered the locus of control scales as the predictors while the lecture and the CAI methods represented the treatments. The Johnson-Neyman procedure defines those regions where a differential assignment of treatments is of statistical significance and benefit to the student. The Johnson-Neyman procedure was performed for the two IAR subscales on the composite sample and is included as an appendix for illustration purposes only.

Discussion of Research Questions

The study was designed and conducted to gain insight into four general research questions. The following discussion presents the original questions with the experimental results and conclusions.

1. Will the distinctly different strategies of traditional lecture and computer-assisted instruction differentially affect academic achievement?

This question was addressed by two research hypotheses, and in the 2-by-2 design of the study, is resolved by an analysis of treatment marginals. Analysis of achievement scores without covariate adjustments resulted in no significant differences on the basis of treatment assignments. Even though the F-ratio probability for the composite sample was within .03 of significance, the hypothesis that differences in achievement are attributable to instructional mode was rejected.

When covariates were included in the analysis only one of the eight variables produced a significant result. When both trials were combined to form the composite sample, the main effect due to treatments reached significance when the MSU math placement score was controlled. This particular score is used to initially place students in their beginning math class at MSU. This measure was considered as one of the primary covariates since it serves as a local measure of entry level ability. This factor reduced the F-ratio probabilities for both trials as well as for the composite sample. It is not surprising, therefore, that this covariate produced a significant effect due to instructional methodology. The lecture method produced higher achievement scores for both samples.

The only other covariate producing a treatment main effect approaching significance was the amount of study time. Although the F-ratio of 3.336 was not large enough to be accepted as significant, the study time factor appears to be one of some importance and should not be ignored. Several other covariate measures reduced F-ratio probabilities but none to a level of statistical significance. The only one to consistently reduce the F-ratio probabilities was the MSU math placement score.

Results of this study indicate that the answer to this research question is a definite no. Even with the lone covariate factor reaching significance, the F-ratio probability (.044) was just barely within the region to reject the null hypothesis. To the extent that this study was able to determine, the method of instruction, lecture or CAI, produced no significant differences in achievement. One could interpret this conclusion as an equivalence of methods and that CAI does just as well as the traditional lecture.

As with most CAI studies, students in the CAI treatment spent less time in formal instruction than lecture students. For the composite sample, the lecture group spent an average of 4.57 hours in formal instruction as opposed to 2.67 hours for the CAI group. Even though the CAI group received 1.9 hours less instructional time--equivalent to two full class periods--their overall performance was no worse than their lecture counterparts. This difference in formal instruction time is highly significant at the $\alpha = .05$ level ($t = 7.82$). This study therefore, joins many others by reporting no improvement or detriment in achievement for CAI but a significant reduction in formal instructional time (a 42% reduction here). The amount of time spent studying outside of class was not statistically significant (t = 1.20) between the lecture and CAI groups although the CAI students reported an average of two hours less study time.

2. Can levels of academic achievement be predicted for the different instructional techniques based on student locus of control measures?

This study approached the locus of control issue in two different ways. The first, and simplest, was to set up internal and external locus of control groups on the basis of the IAR total score. A straight forward ANOVA procedure provided information on whether achievement differences between these two groups existed. Tables 5, 7, and 9 present the results of this analysis. The conclusion reached was that internal and external students performed equally well. The graphs in Figure 2 indicate that achievement scores for each treatment are parallel to a great extent. Contrary to the predictions and results noted in the review of the literature, the trend in this study was for internally oriented students to perform less well than the external students. Although the differences between groups are not statistically significant, this trend is not easily explained.

One possible explanation, however, may be related to the arbitrary classification of internal and external locus of control groups. Assuming a normal distribution of LOC scores, approximately 68% of the sample will have IAR total scores within one standard deviation of the mean. Thirty-four percent of the internally (externally) classified students have IAR total scores within one standard deviation above (below) the sample mean. Cronbach and Snow (1977) contend that treating a continuous measure in a dichotomus manner, although not completely discouraged, tends to obfuscate pertinent results. If the extreme internal and external students of the composite sample (having IAR total scores more than one standard deviation from the mean) are analyzed, the predicted trend emerges. The mean extreme external achievement score is 68.7 (n = 7) while the extreme internal average is 75.6 (n = 9). Such statistical manipulation itself is of little service in interpreting the results. However, it does hint that the expected trend is likely an artifact of the dichotomization of a continuous measure.

Analysis of covariance, the second approach, resulted in no significant differences between internal and external classifications regardless of the covariate. The MSU math placement score analyses yielded increased locus of control F-ratios for each trial and for the composite sample. These increases, however, did not reduce the probabilities to a point of significance. This lone covariate consistantly increased the F-ratios for both the treatment and locus of control main effects. The MSU math placement score may possibly have more influence on achievement than locus of control. As with the previous research question, this one must be answered in the negative--academic achievement is insensitive to a dichotomized student locus of control scale.

3. Does there exist an interaction between instructional methodology and student locus of control?

This question is the type on which ATI research is based. ATI studies are not concerned with whether CAI is better or worse than lecture or with determining the relationship between internal and external students. ATI research efforts attempt to identify stable and, hence, predictable interactions between instructional treatment and student characteristics. This research question was the focal point of this study--does there exist an aptitude-treatment interaction between student locus of control and the instructional paradigms of lecture and CAI?

Four research hypotheses were formulated to address this particular question. The analysis of variance calculation produced a highly non-significant F-ratio for the 2-way interaction between instructional treatment and locus of control classifications. The F-ratios approached zero indicating a complete absence of any interaction whatsoever. Analysis of covariance generally increased the F-ratios regardless of the covariate used. This is expected with F-ratios close to zero--almost anything would help. However, none of the 2-way interactions with or without covariate adjustments reached significance.

As mentioned before, the locus of control measure is a continuous scale with a maximum value of 34--not simply external and internal. The ANOVA and ANCOVA procedures fail to fully utilize the continuous nature of this personality construct. A bilevel blocking on locus of control may, and in this case did, result in a non-significant ANOVA while regression slopes may indeed be significantly different. The ANOVA and ANCOVA procedures also prohibited separate analyses for the I+ and I- subscales of the IAR. Linear regression analysis provided the necessary tool for addressing both issues. This analysis procedure considers the locus of control measure in a quantitative rather than qualitative sense. Despite this quantitative approach, linear regression analysis confirmed the ANOVA and ANCOVA results. The regression slopes for the CAI and lecture regression lines were not significantly different--they were statistically parallel. Parallelism of regression lines occurred when the IAR total score and the I+ and I- subscales were used as the independent variable. Moreover, a test to determine whether the regression slopes were different from zero failed to reach significance (see Appendix E). The student locus of control construct in total or as subscales failed to have any influence on achievement within the confines of this study. No ATI exists for the variables investigated.

The predictions that CAI would benefit the more external student was not realized. The experimental results indicate that the lecture method tended to be better than CAI for all levels of locus of control. CAI students who had extremely external scores on the I- subscale had higher achievement scores than their lecture counterparts. It must be reiterated that achievement scores were not statistically different. The point where the I- scores begin to favor the CAI method is at 5.6 which is below the minimum value of seven observed in the sample.

The expected increase in achievement scores with increased internality did occur for the CAI sections when I+ was the predictor and for the lecture group when I- was the independent measure. Lecture students who attribute success (I+) to their own actions did not perform as well as those expressing the belief that success was mainly due to luck. The nature of the test (problem solving) might have influenced performance when viewed as a function of the I+ subscale. Research has shown that the issue of congruence appears to have some impact on performance. Perhaps the problem solving type of test is more congruous with the CAI treatment. Both require logical, formalized operations, and contain a high degree of structure. The test structure may be incongruous with the lecture style or the manner in which it was conducted. A possible incongruity between expectations in lecture and on the achievement test may explain the declining scores. Lecture students with external beliefs are probably not as affected by any such incongruity with respect to their responsibility for successes.

The trends are reversed when the responsibility for failure scale (I-) is used. Here it is the CAI group that has declining scores for higher levels of personal acceptance of failure. This trend may indicate an incongruity between the student and the CAI instructional method. CAI is a novel use of computers, unfamiliar to most college students. Willing to accept a failure or a substandard performance, these students may have perceived the microcomputer system as threatening or intimidating. CAI students with high I- scores may have also viewed participation in the CAI treatment as a means of taking a short break prior to the final exam. As in the previous discussion on the I+ tendencies, the external I- students are probably unaffected by the means of instruction--failure or success is largely due to luck or chance.

4. Are the results generalizable across student samples?

Since the study consisted of two samples, an indication of the stability and generalizability of the experimental results is available. The results were consistent--no significant treatment effects, locus of control effects, or interactions. Regression analysis of treatments for each trial produced the result of parallel regression lines with slopes statistically equal to zero. Regression lines based on the IAR total score had slopes of the same sign with the lecture method having a larger negative value than the CAI group.

Regression analysis using the I+ and I- subscales was reversed between the two trials. The signs of the lecture and CAI treatments were always the same regardless of trial or subscale. The signs became mixed only in the composite sample. The fact that the I+ scale predicted declining achievement scores in the Winter trial and increasing scores for the Spring trial may be due to a difference in the overall difficulty of the achievement measure. The Winter term average achievement score was significantly higher than that of the Spring trial. All discrimination indices were positive and, except for three items (one on the Winter test and two on the Spring exam), had values of .30 or better. The difficulty indices for the Spring term exam, however, were in a range desirable for good classroom tests. Ebel (1979) states that items with discrimination indices in excess of .30 are reasonably good and may need some improvement. The difficulty of test items in a "good" classroom exam should be in the mid-range of 35-65%. Only one item on the Winter term exam met this recommendation while five of the nine Spring term questions fell in this range with one other within three percentage points. Refer to Appendix D for detailed statistics. The Winter term test, therefore, appears to be less than ideal for the adequate assessment of student ability with the material. The exam was probably too easy, despite the high reliability index and content validity judgements. The Spring term exam in contrast has a better "statistical profile" and may be a better instrument for measuring the effects of the instructional techniques.

The inconsistencies in the I+ and I- regression equations may have resulted in the difference in achievement measures. There may be an exam difficulty factor that influences the I+ and I- results. If the test is initially perceived as difficult, those students who take personal responsibility for success may work at the task in earnest while externally oriented students may work at less than their capacity because the "teacher made a hard test." This logic would explain rising achievement scores and regression lines as represented in the Spring term trial.

The I- regression predictions may be interpreted as due to a heightened level of test anxiety arising from what is perceived as a difficult exam. Students expressing personal responsibility for failure may react in accordance with a perceived exam difficulty level. In an effort to overcome failure a higher level of test anxiety may occur which manifests itself in a debilitating manner, thus causing lower scores. Externally oriented students with respect to the I- scale may not experience any increase in test anxiety and, therefore, perform at higher levels. This logic is again represented by the Spring trial data.

Winter term results for the I- regressions could be due to increased test anxiety manifested as facilitating anxiety because of the relatively easier exam. The regression line slopes, albeit positive, are very small (see Table 12).

The I+ Winter term regression slopes, which are negative and rather large, are more difficult to explain. It would appear that the more internal students didn't really care about their performance. Since the exam was given at the end of the term, internal students may have perceived the importance of the "last exam" before the course final of little consequence. Internal students may have taken a "mental break" because they have enough confidence in themselves to make up for a poor exam score on the final.

Regardless of the above speculations, the dynamics occurring during each trial affected both treatment groups in a consistent manner. If the Spring trial consisted of students who had poorer mathematics backgrounds than the Winter term students, as might be expected, then covariate analyses, especially those using the MSU math placement score and previous math course grade, failed to expose any differential in ability. The fact remains that none of the main effects or interactions were statistically significant for either sample. The results, from a statistical vantage point, are generalizable and stable across student samples.

Reflections and Observations

Many issues pertaining to the conduct and ideas for the improvement of any study emerge as the investigation comes to a close. This section is included to address those issues and concerns, particularly as they relate to the limitations and the experimental procedures.

The study was conducted under a few severe constraints. There was only one microcomputer station available. Even though scheduling students for access to the system afforded all CAI students the time they required, there was very little room for adjustments or rescheduling. If the experiment was of a longer duration or the sample was larger, scheduling regarding microcomputer access would have become problematic. In fact, the system was dedicated to the study at the expense of other office and program concerns. To have extended the duration or increased the sample size would have seriously affected system access for both students and professional staff.

This author was only able to prepare courseware for a fraction of the course material. The preparation time and expense involved with such courseware development is an intensive "front end" investment. Although no accurate records were kept for the time required for courseware preparation, debugging, and student testing, an estimate of 100 hours for each of the three lessons used in this study is reasonable. The cost for preparing courseware, operating the microcomputer system over the expected lifetime of both the hardware and software, and the initial cost and maintenance of the hardware system itself are major concerns for administrators. The initial costs can be substantial and may represent a major expenditure. The unknown cost, of course, is that associated with courseware development and maintenance. The courseware used for this study was specifically designed and written for the subject matter of interest and the available hardware system. Commercially available courseware is scarce and often incompatable with existing course structures or hardware systems. Much of the available courseware, including materials developed for this study, cannot be easily modified or restructured.

The duration of the experiment was limited by the number of microcomputer stations and available courseware. (The equipment demands during the study were almost double the recommended six students to one station ratio.) Even though the literature reports CAI and ATI studies lasting as little as one hour, the three one-hour sessions involved here may have been insufficient for either main or interaction effects to emerge.

The duration of the experimental treatments is related to locus of control in a subtle way. Locus of control, as a measure of generalized expectancy, depends upon the novelty or level of familiarity with a given situation. According to the theory promoted by Rotter (1954), the expected level of achievement is a function of both the specific situation and a generalized expectancy based on the similarity of the given situation to previous situations. Moreover, the impact of the general expectancy is reduced by the frequency with which the student has been in the same or similar situations. The duration of this study, then, focused on the initial experience with a new instructional technique.

Extending the study to cover the entire course would provide information on the more steady state level of expectancy due to the increased familiariy of the CAI system. The intended use of the IAR measure was one of prediction. Data was not collected on student perceptions during various stages of the study. The dynamics involved as students adjusted to the novel CAI method and the correlation of their perceptions with their locus of control scores would have provided a test of the steady state hypothesis.

Of those students electing to remain in lecture rather than participate in the CAI treatment, one observation is noteworthy. These students stated that they felt comfortable with the teacher and were apprehensive about trying something unknown. This reasoning was characteristic of the internal as well as the external students, although the external students were concerned about doing poorly on the exam as a consequence of the CAI technique. Given the option, these students preferred the familiar lecture method rather than an unknown situation. Conversely, there were just as many lecture students, both internal and external, who wanted to work on the computer system. These casual observations tend to reinforce the fact that locus of control is not a factor in pairing instructional methods with students.

The students involved in this study constituted a narrowly defined population. Their IAR total score and subscores were more internal than the more heterogeneous MMM

160 sample. Since the MMM 160 sample consisted of engineering majors but from all levels, freshman through senior, their more external orientation may be due to their college experience. Freshmen tend to be eager and enthusiastic about beginning their college career--it's a novel situation with probably a high level of generalized expectancies. For the more experienced students the college routine is no longer novel but in fact highly structured and regulated. The routinization of college activities may indeed promote a degree of cynicism, leading to the emergence of defensive externals who use the "situation" as a means of protection.

One last observation needs comment. The fact that the students involved in this study were predominantly Black may limit the generalizability of the experimental findings. These students are not simply experiencing a faster, more demanding academic schedule as compared to high school, but they are adjusting to a completely new ond often foreign learning-living environment. The socio-cultural transitions minority students undergo when coming to MSU impact on their academic performance. The extent to which the learning, academic environment intermixes with the new living situation is unknown. While the duration of the study may not have been long enough for the treatments to "take hold", a protracted experiment may have been influenced by transient but significant external factors that impact upon minority freshmen students.

Implications for Continued Research

Like most research studies, this one has raised more questions than it has answered. The obvious questions concerning replication of the results using longer treatment durations, different samples (composition and size), and the choice of subject matter need to be addressed in any future studies. Extending the study to encompass an entire course or course sequence should also be accompanied by methods for determining changes in student locus of control. A detailed study of locus of control changes would provide information pertaining to Rotter's time dependence hypothesis. Using larger, more heterogeneous samples or samples drawn from the extreme locus of control regions would increase the power of the statistical procedures and the validity of the results. Implementation of the above recommendations would necessitate a complete removal of the software and hardware limitations that so constrained this study.

Although limited in scope, this study has indicated that the personality construct of locus of control does not influence differences in academic achievement between instructional methods. Inclusion of more methods and/or affective characteristics may produce the aptitude treatment interactions sought here. Regardless of instructional method, some students did very well and others did very poorly. Locus of control was not a useful measure in explaining academic performance. Measuring test anxiety, experimenting with different test formats, and using interactive computer generated tests for the CAI group compared to pencil and paper tests for the lecture students are other issues requiring attention.

As colleges and universities move toward the next century the influx and proliferation of microcomputers will cause considerable reorganization in the conduct of the educational enterprise. The use and expense of microcomputer systems are major issues confronting administrators and curriculum planners. By 1989, the Massachusetts Institute of Technology and Brown University will invest $70 million each for CAI systems (Ploch, 1984). The University of Michigan is charging each engineering student $100 per term for access to one of four advanced microcomputer systems. (The revenue is allocated for the purchase of newer, more sophisticated systems as they become available.) Stevens Institute of Technology requires each student to purchase microcomputer work stations.

Microcomputer companies, who have traditionally focused on the business and home markets, are now heavily engaged in cultivating the educational market. The leaders currently appear to be IBM and Digital Equipment Corporation followed by Apple, Apollo, and Zenith. These companies are working with college and university administrators to provide hardware components at discounted rates.

The financial stakes for hardware systems alone are very high. The major obstacle, however, is the quantity and quality of the educational courseware. Whether it is of a tutorial, simulation, or artificial intelligence nature, the know-how of CAI courseware development is prerequisite for successful implementation of hardware systems. It was the intent of this study to investigate one aspect of curriculum development as it pertains to CAI material. The development of effective courseware is sure to lag the appearance of CAI work stations, even at the smallest of institutions, for some time to come.

Robinson (1979) contrasts the "traditional" and "modern" educational methods. The traditional method attempts to control all aspects of the learning environment. This system produces "The Child" by requiring students to learn in a uniform, controlled situation, processing information at the same pace and style. The modern method attempts to remove all constraints and open the system up so as to be individualized. From a cybernetic point of view, the modern system is impossible because of the almost infinite variety of student-subject-environment configurations. The result is a mixed system whereby individual needs are addressed within the limitations of a controlled environment. The mixed method of education can be described as a deregulated traditional system or an over regulated modern system. Even though the mixed method cannot theoretically exist because it violates several cybernetic principles, it does exist in a pragmatic sense. This investigation focused on one method for individualizing the educational process by determining which instructional technique promotes higher levels of achievement for particular types of students. Despite the non-significant results, ATI research attempts to remove some of the classroom constraints by optimizing the match between student characteristics and instructional techniques.

There is almost uniform agreement that computer technology has the potential to restructure the educational process. Consequently, the manner in which educational institutions, especially higher education, provide instructional services will also undergo radical change. The manner in which these changes take place over the next few years should be by design and not for convenience. This author does not foresee any hardware limitations. New advances in video capabilities, mass storage devices, and speech synthesis will only promote data, graphics, and audio information processing. The questions facing administrators, curriculum developers, and instructors will center on the effective usage of the advanced technology. These questions can be answered and appropriate decisions made only if adequate knowledge and information exists. Further research into the parameterization of instructional materials, modeling of procedures for the effective diffusion and implementation of the computer into existing educational structures, and the formulation of data driven models of higher education are required.

This research effort in particular and the trend for computerization in general prompt this author to propose the following six research areas.

1. What are the physical and operational features (lesson length, degree of student interactivity, instructional paradigm, on-line questioning protocol, feedback mechanisms, use of color, graphics, speech, etc.) of educational materials that optimize achievement?
2. What student characteristics and instructional methods interact? Locus of control does not appear to be one such parameter, but variables like field dependence-independence, introversion-extroversion, or student attitudes and preferences may be useful in determining appropriate student-methodology pairings.
3. Although not subject to ATI regression techniques, are simple nominal measures such as sex and major preference stronger predictors of achievement than the more quantitative variables?
4. Educational reform is imminent, but at what cost? Institutions of higher education, already operating under often severe financial constraints, must develop sound policies for capital investments pertaining to computer systems, their maintenance, and their access. What is an optimal machine-user ratio? What funding strategies are available for

hardware, software, and courseware purchases? What support systems, personnel, networking capabilities, repair and/or replacement options, software/courseware package requirements are needed? Can cost models be developed for these issues so as to permit comparison and optimization?

5. What control strategies can or should be employed that would maximize long term retention of the subject matter while minimizing cost? When should computers be used and when should they not? Are computer systems going to supplement the traditional forms of instruction or are these powerful machines going to supplant them? Are artificial intelligence systems a viable approach to general undergraduate coursework and, if so, under what conditions should they be used in the classroom?

6. The ultimate question to consider is whether classrooms in the year 2000 will resemble those of today or whether classrooms will indeed exist at all? The growth of the microcomputer industry, while it has possibly saturated the current market, has, nonetheless, been phenomenal. The development of networking systems, satellite communications, and electronic libraries will facilitate long distance or in-home education. Institutions of higher education may become the realm for specialty subjects such as medicine or for advanced graduate research.

> Universities may indeed face a difficult transition period with the advent of electronic undergraduate programs. How are colleges and universities planning to minimize the impact of a computerized education? What decisions need to be made so that computers can be incorporated into higher education with as little disruption as possible?

One of the problems, of course, is that technological development is moving at an ever increasing rate. The latest hardware system today is obsolete within six months. Even though powerful hardware systems exist at reasonable prices, the software necessary to control and operate them, as well as quality courseware, is just now becoming available. Software and courseware development is currently a nascent business.

The intent of this study was to determine whether locus of control could be one of the determining factors in the adoption and use of computer based educational systems. As the diffusion of computers into college classrooms continues, research efforts directed toward better understanding their impact on the learning processes, faculty and students, and the educational institution itself must be studied. These research efforts are requisite for planning and controlling the fourth educational revolution.

APPENDICES

APPENDIX A

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COMPUTER-ASSISTED INSTRUCTION SYSTEM DESCRIPTION

OVERVIEW

This appendix provides a brief overview of the CAI system developed for this study. This discussion also highlights the distinction between the definitions of software and courseware. The design of the CAI system is one of a data processing model. The software (computer programs) were written specifically to create, edit, and process the courseware which serves as the data. The software system is actually an integrated network of six programs. These programs, while performing specific functions, contribute to the overall development, processing, and storage of information related to the instructional materials.

The data processing model uses files which serve as either sources of information or for data storage. Six data files are used in the operation of the CAI system. The contents of these files is presented in this appendix. Also presented are charts depicting the organizational structure and logical processes for the preparation and presentation of instructional materials. Although not used in this study, the CAI system can perform a pre-processing configuration procedure whereby the instructional unit is tailored to the difficulty level of the student currently using the system.

There are a number of special processing commands available for the preparation of instructional materials. These commands constitute an authoring language and a brief description of each command is included. A final section presents two examples of text preparation and processing.

SOFTWARE PROGRAMS

1. CAI Processing Program	- Accessed by the students - Processes instructional courseware - Written in Z-80 assembly
2. Text Entry Program	- Provides authors a method for entering textual materials into the system - Used to create instructional units - Written in Z-80 assembly
3. Curve Generator	- Plots curves and graphs - Permits experimentation with curve parameters before incorporation into instructional units
4. Character Generator	- Permits experimentation with special character and symbol development - Allows permanent storage of character sets
5. File Development Program	- Used to create and update information on data files accessed by the CAI program
6. Summative Data Analysis	- Provides analysis of the instructional units - Performs item analysis - Prepares student progress reports - Lists student comments

DATA FILE CONTENTS

User Verification File

User Name
User Identification Number
User Password
Assigned Instructional Unit
Last Unit Completed
Total Access Time
Number of Accesses
Last Access Date
Instructional Mode
Difficulty Level
Counselor Code

Record Keeping File

User Identification Number
Access Date
Unit Name
Presentation Difficulty Level
Counselor Code
Unit Completion Time
Student Responses
Grading Algorithm Scores

Non-Standard Symbol File

Memory Storage Address
Defining Bytes for Symbol

Grading and Scoring File

Scoring Key Items #1-30
Primary Unit Assignment
Alternate Unit Assignment
Difficulty Level Decisions
Unit Printing Decision
Comment Field

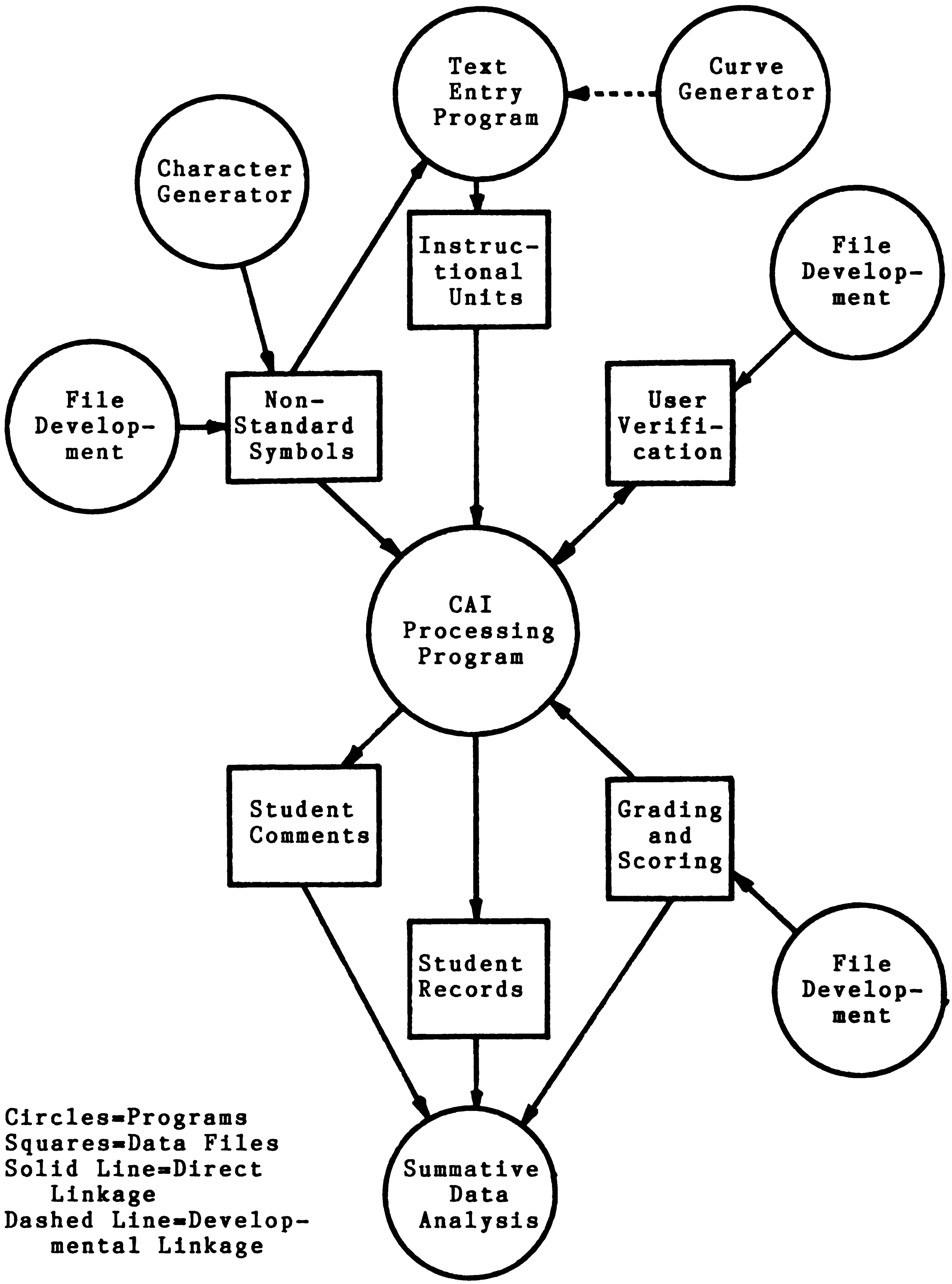
Student Comment File

Unit Name
Comment Field

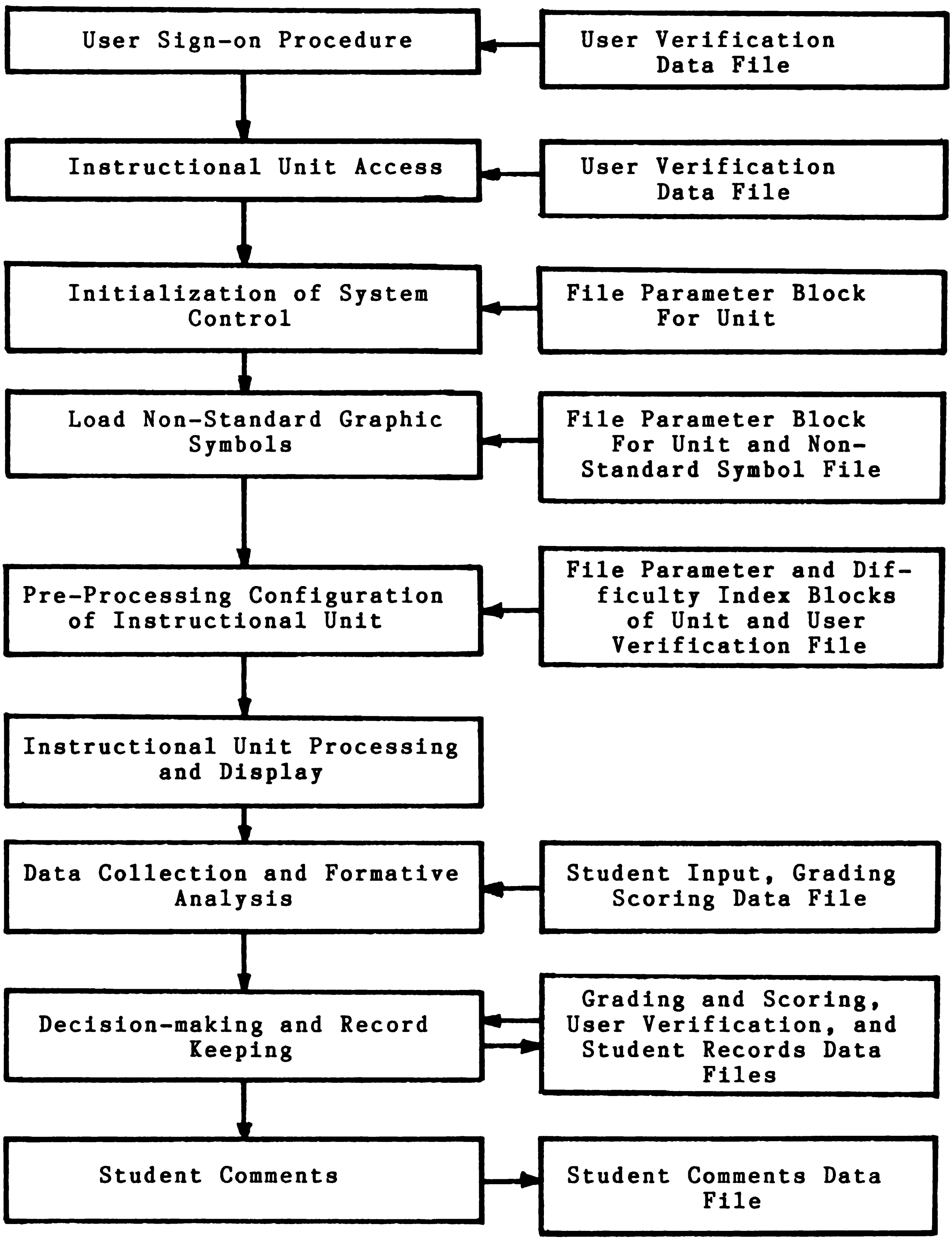
Instructional Units

All instructional material
and processing commands

ORGANIZATIONAL CHART



FLOWCHART AND DATA LINKAGES



TEXT PROCESSING COMMANDS

	Command Name	Purpose
1.	Input Command	To allow students to input answers to questions
2.	Answer Command	Provides immediate feedback indicating correctness of student input
3.	Spacing Command	Used in conjunction with other special processing commands to ensure vertical alignment of characters
4.	Question Command	Identifies the beginning of a question or problem
5.	Random String Command	Indicates number of random variables needed for insertion into a text line
6.	Integer Number Generator	Generates a random integer number
7.	Decimal Number Generator	Generates a random decimal value
8.	Text Phrase Generator	Randomly selects text phrases from a list of possibilities
9.	Compute Command	Computes numerical values in a question using random variables that were previously defined
10.	Compare Command	Used for answer matching when numerical values are input

11.	Foil Command	Calculates numerical multiple-choice foils for questions using randomly generated variables
12.	Select Command	To select text phrases that are dependent on other randomly generated parts of a question, or to prepare textual multiple-choice foils
13.	Plot Command	Plots graphs of math functions and relations
14.	Graphic Characters Command	Loads a new set of graphic characters or symbols into computer memory
15.	On Command	Provides diagnostic feed-back to incorrect answers
16.	Calculate Command	Provides temporary storage for numerical values used in complex calculations
17.	Assembly Language Routine	Loads and/or executes programs written in assembly language
18.	Mapping Command	Provides inverse mapping for multiple-choice foils which were ramdomized prior to presentation--command is generated internally and is not for author use

EXAMPLES

Instructional Unit Coding:*

```
(SP)QSN14.  If (RV) molecules of fluorine react with
(SP)C0006*INT(50*RND(1)+10)
(SP)        phosphorus according to the equation

            P4 + 6F2  ->  4PF3

(SP)        how many molecules of phosphorus trifluoride
(SP)        will be produced?
(SP)FO  4*RVN(1)
(SP)FO  RVN(1)/6
(SP)FO  4*RVN(1)/6
(SP)FOFX4
(SP)IN04
```

Processed Version:

4. If 282 molecules of fluorine react with phosphorus according to the equation

$$P_4 + 6F_2 \rightarrow 4PF_3$$

how many molecules of phosphorus trifluoride will be produced?

A. 1128

B. 47

C. 188

D. 4

What is your answer? __

* The (SP) and (RV) represent single graphic characters used for identifying a special processing command and indicating the position for insertion of random variables.

INT and RND represent the integer and random number functions respectively while RVN is a temporary storage array for numerical values randomly generated within a problem.

Instructional Unit Coding:

```
(SP)QSS1The amount of (RV) an object receives varies
(SP)TX02|heat|light|
(SP)    inversely as the square of the distance from the
(SP)RS01source.  How many times as much (RV) will an object
(SP)SL  RVN(1)|heat|light|
(SP)RS01receive if it is moved to a point (RV) as far away?
(SP)TX04|three times|one-fourth|5 times|two-thirds|
(SP)SL  RVN(3)|one-ninth|16 times|1/25|nine-fourths|
(SP)SL  RVN(3)|9 times|one-sixteenth|25 times|four-ninths|
(SP)SL  RVN(3)|one-sixth|8 times|one-tenth|1 1/2 times|
(SP)SL07RVN(3)|6 times|one-half|10 times|four-thirds|
```

Processed Version:

The amount of light an object receives varies
inversely as the square of the distance from the
source. How many times as much light will an object
receive if it is moved to a point 5 times as far away?

:: 10 times

:: one-tenth

:: 1/25

:: 25 times

This is a concealed multiple-choice item. As each foil is presented, the student has to state whether the foil is the correct answer or is an incorrect solution. An incorrect response from the student or presentation of the correct answer terminates the question. Note that the fourth option will not be presented because the third choice is the right answer. The foils are automatically randomized for this type of item.

APPENDIX B

UNIVERSITY CORRESPONDENCE

MEMORANDA TO UNIVERSITY COMMITTEE ON RESEARCH INVOLVING HUMAN SUBJECTS (UCRIHS)

UCRHIS RESPONSE

MEMORANDUM TO COMMITTEE ON RELEASE OF CONFIDENTIAL INFORMATION

COMMITTEE ON RELEASE OF CONFIDENTIAL INFORMATION RESPONSE

APPENDIX B

January 17, 1983

Menorandum

To: University Committee for Research
Involving Human Subjects

From: Gregory C. Hamilton

Re: Review of Doctoral Research Proposal

Exemption is claimed as type 1 research project.

As a graduate student in the College of Education, I am working on a dissertation for a degree in Administration and Curriculum. The dissertation focuses on comparing traditional lecture versus computer-assisted instructional methodologies for minority engineering students enrolled in one section of the College Algebra course MTH 108. I propose to investigate the existance of an aptitude-treatment interaction between instructional methodology and the affective variable of student locus of control. The class will be divided into two major groups on the basis of student locus of control (Intellectual Achievement Responsibility Questionnaire) and then randomly assigned to one of the two treatment methods. The dependent variable of the study is the score on an achievement test. Analysis will be performed by an analysis of covariance and multilinear regression techniques. The experiment will be performed in the Winter 1983 term and repeated with a second sample in the Spring 1983 term.

For the past eight years I have been employed by the Office of Minority Student Education (OMSE) in the College of Engineering. During that time some of my responsibilities included course and curriculum development. The proposed research project is the culmination of an effort that began three years ago. The students for the project are, therefore, involved in our program and enrolled in a section of Math 108 offered through our office. The students are freshmen ethnic minority students pursuing an engineering degree.

There is no potential risk to the students in any terms. All of the students have knowingly enrolled in the OMSE section of Math 108 for the purpose of obtaining academic instruction in College Algebra as part of the requirements for an engineering degree.

All data collected will be coded to provide the strictest confidentiality. Additional data will be aggregated so that no individual student's identity will be revealed.

The benefits to be gained by the individual student is what we seek to determine. The advent of computer technology is rapidly entering into regular classroom activities even at the collegiate level. The effective usage of computers for instructional purposes depends not only on the computer system and the instructional materials but also on the characteristics of the students using the system. The potential benefits of the study are a better understanding of the interaction effects between affective student characteristics and the method of instruction. Knowledge gained by this and similar studies can be incorporated into aptitude-treatment interaction regression models for the prescription of instructional methodologies compatible with individual learning styles or preferences. The benefits of using microcomputer technology as an instructional tool includes time reduction, cost/student decreases, and as this study intends to investigate, more effective learning for those students who are more responsive to this method of instruction.

The consent procedure will be a verbal request by the instructor of the Math 108 class to the students for voluntary participation in the IAR Questionnaire and the entire study. Since the proposed study does not involve any extraordinary classroom procedures, verbal rather than written consent will be used. Consent from the students will be obtained one week prior to the commencement of the experiment.

The only formal consent form that may be used will be for the collection of covariant data. The form that will be used is attached.

The data collection instruments consist of the IAR Questionnaire (attached), an achievement test, several quizzes, and homework assignments. All measures, except the questionnaire, are being prepared. The content and method of administering the in class measures is a standard practice in the Math 108 class. The questionnaire will be given as a written exercise one week prior to the beginning of the experiment. A verbal description of the study, the procedures to be followed, and the role of the students will be made prior to the administration of the questionnaire.

MICHIGAN STATE UNIVERSITY

COLLEGE OF EDUCATION
DEPARTMENT OF ADMINISTRATION AND CURRICULUM
ERICKSON HALL

EAST LANSING · MICHIGAN · 48824

January 12, 1983

Memorandum

To: UCRIHS

From: Howard W. Hickey
Dissertation Director

Subj: Research Porposal for Gregory C. Hamilton

I have reviewed the research proposal for Gregory C. Hamilton's doctoral thesis and state that it meets with my full approval.

MICHIGAN STATE UNIVERSITY

UNIVERSITY COMMITTEE ON RESEARCH INVOLVING
HUMAN SUBJECTS (UCRIHS)
238 ADMINISTRATION BUILDING
(517) 355-2186

EAST LANSING • MICHIGAN • 48824

February 8, 1983

Mr. Gregory C. Hamilton
Office of Minority Student Education
144 Engineering Building

Dear Mr. Hamilton:

Subject: Proposal Entitled, "The Impact of Student Locus of Control on Academic Achievement as a Function of Lecture Versus Computer-Assisted Instruction"

UCRIHS review of the above referenced project has now been completed. I am pleased to advise that the rights and welfare of the human subjects appear to be adequately protected and the Committee, therefore, approved this project at its meeting on February 7, 1983.

You are reminded that UCRIHS approval is valid for one calendar year. If you plan to continue this project beyond one year, please make provisions for obtaining appropriate UCRIHS approval prior to the anniversary date noted above.

Any changes in procedures involving human subjects must be reviewed by the UCRIHS prior to initiation of the change. UCRIHS must also be notified promptly of any problems (unexpected side effects, complaints, etc.) involving human subjects during the course of the work.

Thank you for bringing this project to our attention. If we can be of any future help, please do not hesitate to let us know.

Sincerely,

Henry E. Bredeck
Chairman, UCRIHS

HEB/jms

cc: Dr. Hickey

MEMORANDUM

To: Dr. Lou Anna K. Simon

From: Gregory C. Hamilton

Date: June 15, 1983

Re: Release of Confidential Information

Pursuant of successful completion of a doctoral degree in Education Administration and Curriculum, I am requesting the release of confidential information for the students on the attached list. Each of these students participated in a research study and signed a consent form. A copy of this form is attached and copies of the signed forms are available upon request.

The purpose of the research study is to investigate the impact student locus of control has on academic achievement as a function of lecture versus computer-assisted instructional methodologies. To properly evaluate this interaction, information pertaining to the students' previous performance and ability is needed. This data is required for multivariant regression analysis procedures. I, therefore, request release of the following data elements for the students listed.

1. MSU Math Placement Score
2. SAT Math Score
3. ACT Math Score
4. Math 082/104 Course Grade
5. Math 108 Course Grade

Thank you for your cooperation.

Enclosures

MICHIGAN STATE UNIVERSITY

OFFICE OF THE PROVOST
ADMINISTRATION BUILDING

EAST LANSING · MICHIGAN · 48824

July 6, 1983

MEMORANDUM

TO: Dr. Charles Eberly
Dr. Horace King

FROM: Lou Anna Kimsey Simon, Assistant Provost LAKS

SUBJECT: Release of Confidential Information

Mr. Gregory C. Hamilton is conducting a doctoral research project to investigate the impact student locus of control has on academic achievement as a function of lecture versus computer-assisted instructional methodologies. This research project was reviewed and approved by the University Committee on Research Involving Human Subjects in February, 1983.

Mr. Harrison has secured individual consent statements from each student in this study to permit the release of confidential information on test scores and grades in selected courses. Attached is a copy of the consent form signed by the students.

Mr. Harrison has provided lists of the students in the study. He has provided to me copies of the signed consent forms. I have checked these forms against the lists and found the lists correspond exactly to the set of consent forms. Therefore, as chairperson of the Committee on Release of Information, I authorize the release of the following information for the students on the attached lists to Mr. Gregory C. Hamilton.

1. MSU Math Placement Score
2. SAT Math Score
3. ACT Math Score
4. Math 082/104 Course Grade
5. Math 108 Course Grade

By copy of this memorandum, I am notifying Mr. Gregory C. Hamilton of this decision and am requesting that he contact Dr. Eberly about the test score information and Dr. King about the course grade information.

Thank you for your support of this project. If you have any questions, please let me know.

LAKS:jm

Attachment

cc: Mr. Gregory C. Hamilton ✓
Mr. Lynn Peltier
Dr. Henry Bredeck

APPENDIX C

RESEARCH FORMS AND QUESTIONNAIRES

RESEARCH PROJECT CONSENT FORM

INTELLECTUAL ACHIEVEMENT RESPONSIBILITY (IAR) QUESTIONNAIRE

MATH 108 RESEARCH STUDY TIME SURVEY

APPENDIX C

Research Project Consent Form

As a student in Math 108, I am freely participating in an educational research project investigating the effectiveness of formal lecture versus computer-assisted instructional techniques. I understand that the following information is needed for statistical analysis purposes. I also understand that this information will be held in the strictest confidence and will eventually be aggregated by the analysis procedures so as to obscure any connection between the data and myself. I, therefore, give consent that the registrar provide the following information to Gregory C. Hamilton: MSU math placement score, SAT math score, ACT math score, and Math 082 and Math 108 course grades. I also consent to the use of quiz, homework, and exam scores in the Math 108 course to be used in the analysis.

Signed ______________________________ Student Number __________

Research Questionnaire Assigned Class Number ____

As part of an educational research study, your cooperation and assistance is needed to obtain data for the purpose of determining several variables pertinent to the project. Please answer each of the following 34 questions by selecting one and only one of the choices. For the results of this survey to be valid and meaningful, each item must be answered this way. There is no "correct" answer and all of your responses will be confidential. Thank you for your time and assistance.

1. If a teacher gives you a good grade in a class, would it probably be

   ___ a. because the teacher liked you, or

   ___ b. because of the work you did?

2. When you do well on a test in school, is it more likely to be

   ___ a. because you studied for it, or

   ___ b. because the test was especially easy?

3. When you have trouble understanding something in school, is it usually

   ___ a. because the teacher didn't explain it clearly, or

   ___ b. because you didn't listen carefully?

4. When you read a story and can't remember much of it, is it usually

   ___ a. because the story wasn't well written, or

   ___ b. because you weren't interested in the story?

5. Suppose your parents say you are doing well in school. Is this likely to happen

   ___ a. because your school work is good, or

   ___ b. because they are in a good mood?

6. Suppose you did better than usual in a subject at school. Would it probably happen

   ___ a. because you tried harder, or

   ___ b. because someone helped you?

7. When you lose at a game of cards or checkers, does it usually happen

___ a. because the other player is good at the game, or

___ b. because you don't play well?

8. Suppose a person doesn't think you are very bright or clever.

___ a. can you make him change his mind if you try to, or

___ b. are there some people who will think you're not very bright no matter what you do?

9. If you solve a puzzle quickly, is it

___ a. because it wasn't a very hard puzzle, or

___ b. because you worked on it carefully?

10. If someone tells you that you are dumb, is it more likely that they say that

___ a. because they are mad at you, or

___ b. because what you did really wasn't very bright?

11. Suppose you study to become a teacher, scientist, or doctor and you fail. Do you think this would happen

___ a. because you didn't work hard enough, or

___ b. because you needed some help and other people didn't give it to you?

12. When you learn something quickly in school, is it usually

___ a. because you paid close attention, or

___ b. because the teacher explained it clearly?

13. If a teacher says to you, "Your work is fine," is it

___ a. something teachers say to encourage students, or

___ b. because you did a good job?

14. When you find it hard to work arithmetic or math problems at school, is it

    ___ a. because you didn't study well enough before you tried them, or

    ___ b. because the teacher gave problems that were too hard?

15. When you forget something you heard in class, is it

    ___ a. because the teacher didn't explain it very well, or

    ___ b. because you didn't try very hard to remember?

16. Suppose you weren't sure about the answer to a question your teacher asked you, but your answer turned out to be right. Is it likely to happen

    ___ a. because she wasn't as particular as usual, or

    ___ b. because you gave the best answer you could think of?

17. When you read a story and remember most of it, is it usually

    ___ a. because you were interested in the story, or

    ___ b. because the story was well written?

18. If your parents tell you you're acting silly or not thinking clearly, is it more likely to be

    ___ a. because of something you did, or

    ___ b. because they happen to be feeling cranky?

19. When you don't do well on a test at school, is it

    ___ a. because the test was especially hard, or

    ___ b. because you didn't study for it?

20. When you win at a game of cards or checkers, does it happen

    ___ a. because you play real well, or

    ___ b. because the other person doesn't play well?

21. If people think you're bright or clever, is it

    ___ a. because they happen to like you, or

    ___ b. because you usually act that way?

22. If a teacher fails you in a course, would it probably be

___ a. because the teacher "had it in for you," or

___ b. because your school work wasn't good enough?

23. Suppose you don't do as well as usual in a subject at school. Would this probably happen

___ a. because you weren't as careful as usual, or

___ b. because somebody bothered you and kept you from working?

24. If someone tells you that you are bright, is it usually

___ a. because you thought up a good idea, or

___ b. because they like you?

25. Suppose you become a famous teacher, scientist, or doctor. Do you think this would happen

___ a. because other people helped you when you needed it, or

___ b. because you worked very hard?

26. Suppose your parents say you aren't doing well in your school work. Is this likely to happen more

___ a. because your work isn't very good, or

___ b. because they are feeling cranky?

27. Suppose you are showing a friend how to play a game and he has trouble with it. Would that happen

___ a. because he wasn't able to understand how to play, or

___ b. because you couldn't explain it well?

28. When you find it easy to work arithmetic or math problems at school, is it usually

___ a. because the teacher gave you especially easy problems, or

___ b. because you studied your book well before you tried them?

29. When you remember something you heard in class, is it usually

___ a. because you tried hard to remember, or

___ b. because the teacher explained it well?

30. If you can't work a puzzle, is it more likely to happen

___ a. because you are not especially good at working puzzles, or

___ b. because the instructions weren't written clearly enough?

31. If your parents tell you that you are bright or clever, is it more likely

___ a. because they are feeling good, or

___ b. because of something you did?

32. Suppose you are explaining how to play a game to a friend and he learns quickly. Would that happen more often

___ a. because you explained it well, or

___ b. because he was able to understand it?

33. Suppose you're not sure about the answer to a question your teacher asks you and the answer you give turns out to be wrong. Is it likely to happen

___ a. because the teacher was more particular than usual, or

___ b. because you answered too quickly?

34. If a teacher says to you, "Try to do better," would it be

___ a. because this is something teachers might say to get students to try harder, or

___ b. because your work wasn't as good as usual?

Math 108 Research Survey   Assigned Class Number _____

The amount of time you spend in a formal educational setting (lecture/computer) is only a fraction of the total time spent studying the material. Consequently, much of the actual learning takes place outside of the classroom. To finish up the research study would you kindly take a few minutes to complete the following form.

Topic	Section	Lecture Date	Study Time PRIOR to class	Study Time AFTER Class
The Complex Numbers Complex Roots of Equations	10.1 10.2	May 19	_______hr.	______hrs.
Poynomials, Remainder and Factor Theorems	11.1	May 20	_______hr.	______hrs.
Synthetic Division	11.2	May 23	_______hr.	______hrs.
Zeroes of Polynomials	11.3	May 24	_______hr.	______hrs.
The Rational Root Theorem	11.4	May 25	_______hr.	______hrs.
Exam	—	May 27	_______hr.	

As always, results will be kept in the strictest confidence.

APPENDIX D

ACHIEVEMENT INSTRUMENTS

INSTRUCTIONAL OBJECTIVES

WINTER TRIAL EXAM AND STATISTICS

SPRING TRIAL EXAM AND STATISTICS

APPENDIX D

INSTRUCTIONAL OBJECTIVES

Lesson 1.

Add, subtract, multiply, and divide complex numbers.

Solve linear, quadratic, and cubic equations with complex and/or real coefficients.

Lesson 2.

Add, subtract, and multiply polynomials of varying degrees.

Find the quotient and remainder functions Q(x) and R(x) when a given polynomial P(x) is divided by a given D(x) function.

Use the Remainder Theorem to determine if (x - r) is a factor of a given P(x) polynomial.

Use the Remainder Theorem to evaluate the polynomial P(x) for a given value of x.

Use synthetic division of polynomials when the divisor, D(x), has the form (x - r).

Lesson 3.

Find a polynomial of lowest degree when given its roots and their multiplicities.

Given a polynomial and some of its roots, find the other roots.

Given a polynomial with integer or rational coefficients, find all of the rational roots.

TUTOR ________________ NAME ____________________

W '83 108 TEST 5 STUDENT NUMBER __________

1. (12 pts) Simplify, write the answers in the form a + bi .

a) i^{407}

b) $\frac{3 + 2i}{i} - \frac{2 - i}{3 - 2i}$

2. (12 pts) Solve for x and y real.

$$2^x + \frac{1}{9}i = 8 + (\log_3 y)i$$

3. (12 pts) Find ALL solutions to $x^3 = 27$ expressing the complex solutions in the a + bi form.

4. (10 pts) Derive equations sufficient to determine A & B , such that (x - 1) and (x + 2) are factors of $f(x) = 2x^3 + Ax^2 + Bx - 12$. Just derive the equations, DO NOT SOLVE.

5. (6 pts) What is the remainder when $2x^{100} - 3x^5 + 4$ is divided by (x + 1) . Show your method.

6. (10 pts) Find the quotient q(x) and remainder r(x) if $f(x) = 2x^4 + 3x^3 + 9x^2 + 13x + 5$ is divided by $g(x) = x^2 + 4$.

7. (10 pts) Use synthetic division to find the quotient $q(x)$ and remainder r when $(5x + 3x^4 - 7x^3 + 1)$ is divided by $(x - 2)$.

8. (10 pts) Find a polynomial of lowest degree with zeros 2, $1 + i$, $-i$ if a) the coefficients may be nonreal, and b) the coefficients must be real. Leave in factored form.

9. (18pts) Find ALL the zeros of $f(x) = 2x^3 + x^2 + 1$.

Statistics: Test 5, Winter 1983

Item	Pt. Value	Average	St. Dev.	Disc	Diff
1	12	8.75	2.36	0.53	73.33
2	12	10.63	3.26	0.58	76.67
3	12	8.66	3.91	0.68	70.00
4	10	6.22	2.56	0.45	57.00
5	6	5.66	1.13	0.38	85.00
6	10	8.41	2.68	0.42	80.00
7	10	9.63	0.96	0.00	100.00
8	10	7.47	2.61	0.38	75.00
9	18	15.13	4.11	0.50	76.11

Test Ave. = 80.53 St. Dev. = 15.51 Number of exams = 32

Exam Reliability Index = 0.79

TUTOR ____________________ NAME ____________________

108 SP '83 STUDENT NUMBER ____________

TEST 5

1. (12 pts.) Write each in simplest form.

   a) $\sqrt{-2} \cdot \sqrt{-5} =$

   b) $i^{211} =$

   c) The remainder when $x^{11} - x^2 + 3$ is divided by $x + 1$ is ______________

2. (12 pts.) Solve for z expressing the solution in the $a + bi$ form.

$$(2 + i)z = 3z + 6 + 3i$$

3. (12 pts.) Find all real and complex solutions to $x^3 + 64 = 0$. Express the complex solutions in the $a + bi$ form.

4. (9 pts.) Solve for x and y real.

$$2^y + 2i = \frac{1}{4} + i \log_4 x$$

5. (10 pts.) Determine k such that $x + 2$ is a factor of $x^3 + kx^2 - kx - 10$.

6. (10 pts.) Find the quotient $q(x)$ and remainder $r(x)$ if $f(x) = 8x^3 - 6x^2 - 4x$ is divided by $g(x) = 2x^2 - x + 1$.

7. (10 pts) Use synthetic division to find the quotient and remainder when $7x^8 + 3x^5 - x^2 + 10$ is divided by $x - 1$.

8. (10 pts.) Find a polynomial of lowest degree with the given zeros if a) the coefficients may be nonreal b) the coefficients <u>must</u> be real. The zeros are 3, $3 + 2i$, and $2 - 3i$. Leave answers in factored form.

9. (15 pts.) Find all the zeros of $5x^3 - x^2 - 15x + 3$.

Statistics: Test 5, Spring 1983

Item	Pt. Value	Average	St. Dev.	Disc	Diff
1	12	8.89	3.19	0.52	65.63
2	12	7.26	4.06	0.83	54.17
3	12	5.11	4.48	0.50	45.83
4	9	4.74	3.09	0.50	58.33
5	10	8.53	2.74	0.15	92.50
6	10	6.95	3.07	0.30	80.00
7	10	8.63	1.69	0.27	86.25
8	10	5.84	2.70	0.45	52.50
9	15	9.05	4.26	0.48	67.50

Test Ave. = 65.00 St. Dev. = 16.56 Number of exams = 19

Exam Reliability Index = 0.71

APPENDIX E

JOHNSON-NEYMAN PROCEDURE

INTRODUCTION AND DISCUSSION

CALCULATIONS FOR I^+ COMPOSITE DATA

CALCULATIONS FOR I^- COMPOSITE DATA

APPENDIX E

JOHNSON-NEYMAN PROCEDURE

INTRODUCTION AND DISCUSSION

This appendix provides a comprehensive discussion of the Johnson-Neyman procedure for determining regions of significance given the existence of significant interaction effects. Although no such interactions were found in this study, this appendix is provided as an illustration of the technique. Readers are cautioned that the discussion provided herein are not to be considered as empirical findings of this research effort.

The original formulation of this procedure (Johnson & Neyman, 1936) used two groups, two predictor measures, and one criterion variable. The theory has been extended to include any number of groups, predictors, and criterion measures (Abelson, 1953; Cahen & Linn, 1971; Carroll & Wilson, 1970; Johnson & Fay, 1950; Koenker & Hansen, 1942; Potthoff, 1964). The present application involves two groups, a single predictor, and one criterion variable. The applications presented in the latter sections of the appendix are patterned after the Johnson and Jackson (1959) examples, specifically those beginning on page 432. Setting aside the fact that no ATI exists and, for the purposes of illustration only, rejecting the hypothesis of equal regression slopes, the following is a presentation of the Johnson-Neyman procedure.

The crux of this procedure is to identify those values of the independent variable(s) which predict statistically significant differences in the dependent variable(s). Referring back to Figure 3, the treatment lines based on the I+ score would cross at I+ = 19.3 if the scale extended that far. The extreme left region of the scale shows what appears to be a substantial difference in the predicted achievement scores; a difference of over 30 points exists at I+ = 0. The task is to determine which value or values of I+ (and I-) form the boundaries between equivalent and non-equivalent treatments. Putting this in the context of the I+ graph, does the value of I+ = 10, for example, create one region, (I+ < 10), for which the lecture mode is significantly superior to CAI and another region (I+ > 10) where there is no statistical difference between them?

For a single predictor variable the regions of significance are determined by a quadratic equation in one variable. The solutions provide two values of the predictor which can be represented by vertical lines on a graphical display. If two predictors are used the problem usually becomes one of defining ellipses on two-dimensional predictor planes (Cahen & Linn, 1971). As more variables are included, the complexity of the significant regions in the variable space becomes increasing complex as well. For the present discussion the equations that the Johnson-Neyman procedure produce are presented in Table 15.

Table 15

Illustration of the
Johnson-Neyman Procedure:
Equations and Solutions for
Regions of Significance
I+ and I- Regressions

Predictor	Equations for Significance	Solutions
I+	$24.30X^2 - 659.30X + 4515.23 = 0$	$X = 13.6 \pm 1.33i$
I-	$21.28X^2 - 579.01X + 3983.71 = 0$	$X = 13.6 \pm 1.45i$

The imaginary components are a result of the large variance terms (constants) in the equations. This is probably a reflection of the lack of any ATI which is prerequisite for obtaining meaningful results. Although the issue of imaginary solutions is not addressed in the literature, and since this is presented for illustrative purposes only, this author will take the liberty of ignoring these terms. The regions of significance are graphed in Figures 5 and 6. Values of I+ less than 13.6 would indicate that the lecture method is significantly better than CAI. Students having I+ scores greater than 13.6 would do equally well with either method. The I- graph shows that students having I- scores in excess of 13.6 would do better with the lecture method

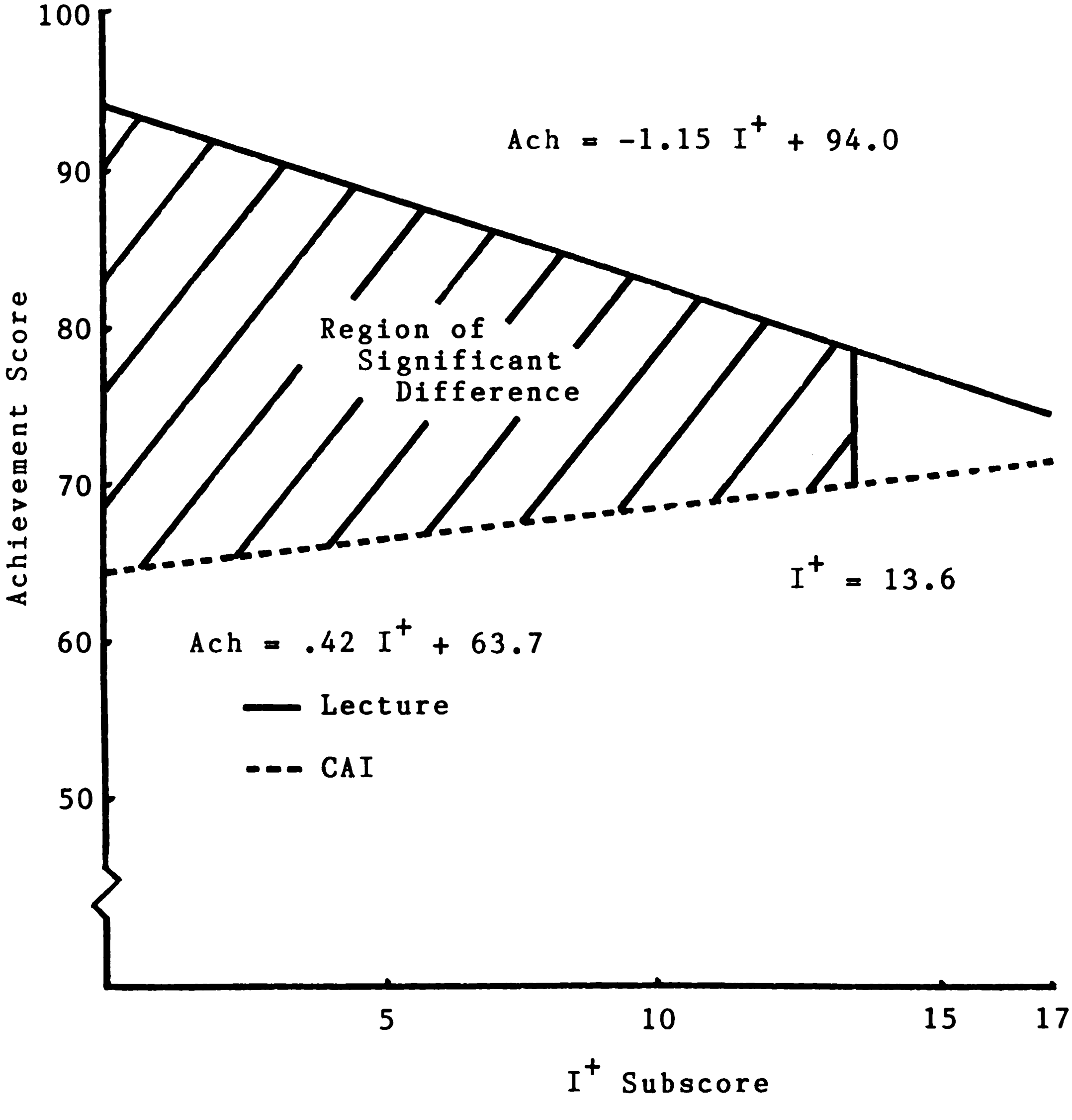


Figure 5

Region of Significance for I^+ Subscale
Composite Sample
Illustration of Johnson-Neyman Procedure

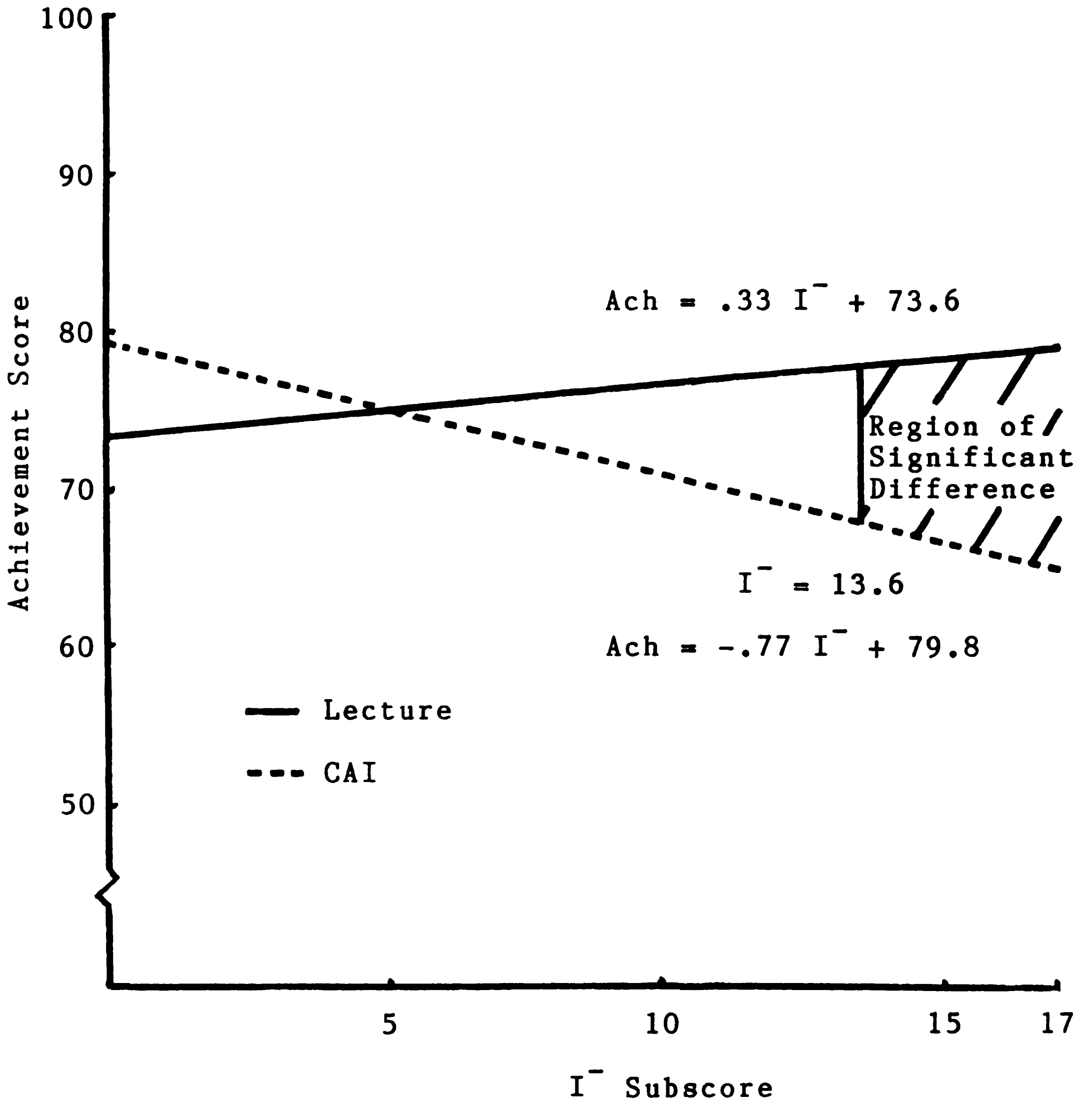


Figure 6

Region of Significance for I^- Subscale
Composite Sample
Illustration of Johnson-Neyman Procedure

while students with low I- scores should perform equally well regardless of instructional method. The predicted differences in achievement scores at the cut-off points are 9.0 and 8.7 for the I+ and I- predictors respectively.

The last question is how many students fall into these regions of significance? Table 16 provides the number and percentage of students who, based on the preceeding analysis, would benefit from the lecture method.

Table 16

Locus of Control Conditions
Predicting Lecture Assignment

	Study Sample		MMM 160 Sample	
Decision Rule	N	%	N	%
1. I+ < 13.6	19	37.3	27	47.4
2. I- > 13.6	27	52.9	14	24.6
3. I+ < 13.6 or I- > 13.6	36	70.6	37	64.9
4. I+ < 13.6 and I- > 13.6	10	19.6	4	7.0

The table presents information for students in the composite study sample and the slightly larger MMM 160 group. The differential assignment of the lecture method is determined by the regions of significance. Assignments can be made according to one of four decision rules with the joint condition that I+ and I- both be in the regions of significance being the most strict. Assuming this analysis is valid, these values show that only 10-20% of the students would definitely benefit from the lecture treatment. The remaining 80-90% of the class would perform equally well with either treatment.

Readers are again cautioned that this discussion has been for illustrative purposes only and the results are not the conclusions forwarded as part of the research.

CALCULATIONS FOR I^+ COMPOSITE DATA

Table 17

I+ Composite Data Work Sheet

	Lecture				CAI			
	External		Internal		External		Internal	
	I+	Ach	I+	Ach	I+	Ach	I+	Ach
1	15	95	14	93	15	84	17	63
2	11	90	17	14	14	80	17	92
3	15	98	17	89	12	73	16	76
4	13	55	14	72	13	76	16	65
5	11	78	16	81	11	84	16	57
6	11	94	15	87	12	90	15	67
7	14	90	14	82	15	88	13	69
8	14	85	13	90	12	61	16	45
9	10	71	14	85	12	72	17	61
10	13	95	16	84	11	23		
11	11	54	17	78	15	68		
12	13	98	15	61				
13	15	64	15	61				
14	11	79	16	92				
15			13	52				
16			14	88				
17			16	63				
n	14	14	17	17	11	11	9	9
Σx	177	1146	256	1272	142	799	143	595
$\bar{x}$	12.6	81.86	15.1	74.82	12.9	72.64	15.9	66.11
Σx^2	2279	96922	3884	101592	1858	61519	2285	40679
σ^2	3.17	239.52	1.81	401.03	2.49	348.25	1.61	167.86
Σxz	14584		19058		10437		9462	
N	31				20			
Σx	433				285			
Σz	2418				1394			
Σx^2	6163				4143			
Σz^2	198514				102198			
Σxz	33642				19899			
S_{xx}	114.97				81.75			
S_{zz}	9910.22				5036.27			
S_{xz}	-132.00				34.50			

Step 1: $S^2_{z.x1} = S_{zz1} - S^2_{zx1}/S_{xx1}$

$$= 9910.22 - (132)^2/114.97 = 9758.67$$

$$S^2_{z.x2} = S_{zz2} - S^2_{zx2}/S_{xx2}$$

$$= 5036.27 - (34.5)^2/81.75 = 5021.71$$

$$F = \left(\frac{N_2-2}{N_1-2}\right) \cdot \frac{S^2_{z.x1}}{S^2_{z.x2}} = \left(\frac{18}{29}\right)\left(\frac{9758.67}{5021.71}\right) = 1.21$$

$F_{20,29,.05} = 1.94$ so result is not significant

Therefore $\sigma_1 = \sigma_2$ Equal variances of $\hat{Z}$.

Step 2: $N_T = 51$ $\Sigma x_T^2 = 10306$

$\Sigma x_T = 718$ $\Sigma z_T^2 = 300712$

$\Sigma z_T = 3812$ $\Sigma x_T z_T = 53541$

$S_{zzT} = 15783.4$ $S_{xxT} = 197.69$ $S_{xzT} = -125.98$

Source of Variation	df	SS_z	SS_x	Sum of Products	Regression Coef.
Between	1	836.91	.97	-28.48	29.36
Within Lec.	30	9910.22	141.97	-132.00	-1.15
Within CAI	19	5036.27	81.75	34.50	.42
Total Within	49	14946.49	196.72	-97.50	-.50
Total	50	15783.40	197.69	-125.98	-.64

Step 3:

Source of Variation	df	Sum of Squares	Mean Square
Total Within Group Residual	48	14805.6	308.45
Total Residual	49	15703.1	--
Difference	1	897.5	897.5

$F = 897.5/308.45 = 2.91 \qquad n_1 = 1;\ n_2 = 48$

F needed for significance = 4.04

Therefore, $A_1 = A_2$

Step 4a:

Residual Sum of Square of Z	df	Sum of Squares	Mean Square
Within Lecture	29	9758.67	--
Within CAI	18	5021.71	--
Subtotal	47	14780.38	314.48
Total Within	48	14805.60	308.45
Difference Between Regression Coef.	1	25.22	25.22

$F = 314.48/25.22 = 12.47 \qquad n_1 = 47;\ n_2 = 1$

F needed for significance = 252

Therefore, $B_1 = B_2$

b. Test for B = 0

$$\frac{(S_{zx1} + S_{zx2})^2}{(S_{xx1} + S_{xx2})} = \frac{(-132.0 + 34.50)^2}{(114.97 + 81.75)} = 48.32$$

$$F = \frac{48.32}{308.45} = .16 \quad \text{Not significant}$$

So, $B_1 = B_2 = 0$

Step 5: Assuming that $A_1 \neq A_2$ and $B_1 \neq B_2$ then:

$$\hat{Z}_1 = -1.15\ X + 94.0$$

$$\hat{Z}_2 = .42\ X + 63.7$$

$$D = \hat{Z}_1 - \hat{Z}_2 = -1.57\ X + 30.3$$

$$F = \left(\frac{n_1 + n_2 - 4}{1}\right) \cdot \frac{D^2}{(P+Q)\ S_a^2} \qquad F_{1,47,.05} = 4.045$$

$$D^2 \geq F(P+Q)\left(\frac{S_a^2}{n_1 + n_2 - 4}\right)$$

$$P+Q = \frac{n_1+n_2}{n_1 n_2} + \frac{(x-x_{1.})^2}{S_{xx1}} + \frac{(x-x_{2.})^2}{S_{xx2}}$$

$$P+Q = \frac{31+20}{31x20} + \frac{(x-13.97)^2}{114.97} + \frac{(x-14.25)^2}{81.75}$$

$$P+Q = .021x^2 - .592x + 4.264$$

$$S_a^2 = S_{z.x1}^2 + S_{z.x2}^2 = 9758.67 + 5021.71 = 14805.6$$

Substituting:

$$(-1.57x + 30.3)^2 \geq (4.045)(.021x^2 - .592x + 4.264)\left(\frac{14805.6}{47}\right)$$

Rearranging:

$$0 \geq 24.30x^2 - 659.30x + 4515.23$$

Using the quadratic formula to solve for x yields:

$$x = 13.6 + 1.33i \quad \text{and} \quad x = 13.6 - 1.33i$$

CALCULATIONS FOR I^- COMPOSITE DATA

Table 18

I- Composite Data Work Sheet

	Lecture				CAI			
	External		Internal		External		Internal	
	I-	Ach	I-	Ach	I-	Ach	I-	Ach
1	11	95	16	93	11	84	16	63
2	11	90	12	14	11	80	15	92
3	12	98	15	89	7	73	15	76
4	14	55	16	72	14	76	13	65
5	16	78	14	81	14	84	14	57
6	14	94	13	87	15	90	13	67
7	11	90	16	82	12	88	15	69
8	11	85	16	90	13	61	15	45
9	11	71	15	85	10	72	16	61
10	12	95	15	84	13	23		
11	12	54	15	78	10	68		
12	8	98	12	61				
13	11	64	13	61				
14	15	79	15	92				
15			14	52				
16			15	88				
17			14	63				
n	14	14	17	17	11	11	9	9
Σx	169	1146	246	1272	130	799	132	595
$\bar{x}$	12.1	81.86	14.5	74.82	11.8	72.64	14.7	66.11
Σx^2	2095	96922	3588	101592	1590	61519	1946	40679
σ^2	4.23	239.52	1.76	401.03	5.36	348.25	1.25	167.86
Σxz	13712		18700		9453		8728	
N	31				20			
Σx	415				262			
Σz	2418				1394			
Σx^2	5683				3536			
Σz^2	198514				102198			
Σxz	32412				18181			
S_{xx}	127.35				103.80			
S_{zz}	9910.22				5036.27			
S_{xz}	42.00				-80.40			

Step 1: $S^2_{z.x1} = S_{zz1} - S^2_{zx1}/S_{xx1}$

$$= 9910.22 - (42.0)^2/127.35 = 9896.37$$

$$S^2_{z.x2} = S_{zz2} - S^2_{zx2}/S_{xx2}$$

$$= 5036.27 - (80.4)^2/103.80 = 4974.0$$

$$F = \left(\frac{N_2-2}{N_1-2}\right) \cdot \frac{S^2_{z.x1}}{S^2_{z.x2}} = \left(\frac{18}{29}\right)\left(\frac{9896.37}{4974.00}\right) = 1.23$$

$F_{20,29,.05} = 1.94$ so result is not significant

Therefore $\sigma_1 = \sigma_2$ Equal variances of $\hat{Z}$.

Step 2: $N_T = 51$ $\Sigma x_T^2 = 9219$

$\Sigma x_T = 677$ $\Sigma z_T^2 = 300712$

$\Sigma z_T = 3812$ $\Sigma x_T z_T = 50593$

$S_{zzT} = 15783.4$ $S_{xxT} = 232.16$ $S_{xzT} = -9.43$

Source of Variation	df	SS_z	SS_x	Sum of Products	Regression Coef.
Between	1	836.91	1.01	28.17	27.89
Within Lec.	30	9910.22	127.35	42.00	.33
Within CAI	19	5036.27	103.80	-80.40	-.77
Total Within	49	14946.49	231.15	-37.60	-.16
Total	50	15783.40	232.16	-9.43	-.04

Step 3:

Source of Variation	df	Sum of Squares	Mean Square
Total Within Group Residual	48	14881.7	310.04
Total Residual	49	15783.0	--
Difference	1	842.9	842.9

$F = 842.9/310.04 = 2.72 \qquad n_1 = 1;\ n_2 = 48$

F needed for significance = 4.04

Therefore, $A_1 = A_2$

Step 4a:

Residual Sum of Square of Z	df	Sum of Squares	Mean Square
Within Lecture	29	9896.37	--
Within CAI	18	4974.00	--
Subtotal	47	14870.37	316.39
Total Within	48	14881.70	310.04
Difference Between Regression Coef.	1	11.33	11.33

$F = 316.39/11.33 = 27.93 \qquad n_1 = 47;\ n_2 = 1$

F needed for significance = 252

Therefore, $B_1 = B_2$

b. Test for B = 0

$$\frac{(S_{zx1} + S_{zx2})^2}{(S_{xx1} + S_{xx2})} = \frac{(42.0 - 80.40)^2}{(127.35 + 103.80)} = 6.38$$

$$F = \frac{6.38}{310.04} = .02 \qquad \text{Not significant}$$

So, $B_1 = B_2 = 0$

Step 5: Assuming that $A_1 \neq A_2$ and $B_1 \neq B_2$ then:

$$\hat{Z}_1 = .33\ X + 73.6$$

$$\hat{Z}_2 = -.77\ X + 79.8$$

$$D = \hat{Z}_1 - \hat{Z}_2 = 1.10\ X - 6.2$$

$$F = \left(\frac{n_1 + n_2 - 4}{1}\right) \cdot \frac{D^2}{(P+Q)\ S_a^2} \qquad F_{1,47,.05} = 4.045$$

$$D^2 \geq F(P+Q)\left(\frac{S_a^2}{n_1 + n_2 - 4}\right)$$

$$P+Q = \frac{n_1+n_2}{n_1 n_2} + \frac{(x-x_{1.})^2}{S_{xx1}} + \frac{(x-x_{2.})^2}{S_{xx2}}$$

$$P+Q = \frac{31+20}{31x20} + \frac{(x-13.39)^2}{127.35} + \frac{(x-13.10)^2}{103.80}$$

$$P+Q = .018x^2 - .463x + 3.143$$

$$S_a^2 = S_{z.x1}^2 + S_{z.x2}^2 = 9896.37 + 4974.00 = 14870.4$$

Substituting:

$$(1.10x - 6.2)^2 \geq (4.045)(.018x^2 - .463x + 3.143)\left(\frac{14870.4}{47}\right)$$

Rearranging:

$$0 \geq 21.28x^2 - 579.01x + 3983.71$$

Using the quadratic formula to solve for x yields:

$$x = 13.6 + 1.45i \quad \text{and} \quad x = 13.6 - 1.45i$$

REFERENCE NOTES

REFERENCE NOTES

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