INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

UMI
University Microfilms International
A Bell & Howell Information Company
300 North Zeeb Road. Ann Arbor, MI 48106-1346 USA
313/761-4700  800-521-0600
The effects of an integrated learning system (ILS) using incremental time allotments on ninth-grade algebra achievement

West, Robert Charles, Ph.D.

Wayne State University, 1992

Copyright ©1992 by West, Robert Charles. All rights reserved.
THE EFFECTS OF AN INTEGRATED LEARNING SYSTEM (ILS)
USING INCREMENTAL TIME ALLOTMENTS ON NINTH GRADE
ALGEBRA ACHIEVEMENT

by

ROBERT CHARLES WEST

Dissertation

Submitted to Graduate School
of Wayne State University,

Detroit, Michigan
In partial fulfilment of the requirements
for the Degree of

DOCTOR OF PHILOSOPHY

1992

Major: EVALUATION
AND RESEARCH

Approved by:

Advisor

date

[Signatures]
Dedication

To Erin, Elaine, Paul and Adrienne, and most of all to Jan, whose support and sacrifice made all this possible.
Acknowledgment

I wish to note the deep appreciation for the assistance and support offered by my committee members, Dr. Donald Marcotte, Dr. Shlomo Sawilowsky, Dr. John Norman, and Dr. John Waller for their experienced influence on my work. My work was also greatly eased by the contributions of Dr. Donald Mys. Finally, the extensive help offered by the members of the Research Support Laboratory are deeply appreciated including Elaine Hockman, Hamid Siddiqui, Rakad Arraf, Steve Wolfel and Brian Townsend.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dedication</td>
<td>ii</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>iii</td>
</tr>
<tr>
<td>I. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Overview of Problem</td>
<td>1</td>
</tr>
<tr>
<td>Problem Statement</td>
<td>1</td>
</tr>
<tr>
<td>Significance of Problem</td>
<td>3</td>
</tr>
<tr>
<td>Definition of Terms</td>
<td>5</td>
</tr>
<tr>
<td>Historical Perspective</td>
<td>6</td>
</tr>
<tr>
<td>II. Review of Literature</td>
<td>11</td>
</tr>
<tr>
<td>Meta-analysis</td>
<td>11</td>
</tr>
<tr>
<td>Integrated Learning Systems (ILS)</td>
<td>12</td>
</tr>
<tr>
<td>Benefits of Active Visual Presentation</td>
<td>13</td>
</tr>
<tr>
<td>Effects of Personality Traits</td>
<td>14</td>
</tr>
<tr>
<td>Effects of Student Feedback</td>
<td>16</td>
</tr>
<tr>
<td>Effects of the Order of Presentation</td>
<td>20</td>
</tr>
<tr>
<td>Time on Task</td>
<td>21</td>
</tr>
<tr>
<td>Fisher's Model of Academic Learning Time (ALT)</td>
<td>22</td>
</tr>
<tr>
<td>The Relation Between ALT and ILS</td>
<td>25</td>
</tr>
<tr>
<td>ILS's Greater Efficiency</td>
<td>27</td>
</tr>
<tr>
<td>Previous Verbal and Mathematics Achievement and Sex</td>
<td>29</td>
</tr>
<tr>
<td>The Effects of Personal Attitudes and Social Influences</td>
<td>31</td>
</tr>
<tr>
<td>Marsh's Self Concept Model</td>
<td>32</td>
</tr>
<tr>
<td>III. Methodology</td>
<td>35</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>----</td>
</tr>
<tr>
<td>Design</td>
<td>35</td>
</tr>
<tr>
<td>Instrument</td>
<td>38</td>
</tr>
<tr>
<td>Variables</td>
<td>45</td>
</tr>
<tr>
<td>Sample</td>
<td>46</td>
</tr>
<tr>
<td>Scales of Measurement</td>
<td>47</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>47</td>
</tr>
<tr>
<td>IV. Results</td>
<td>51</td>
</tr>
<tr>
<td>Zero-order Correlations</td>
<td>51</td>
</tr>
<tr>
<td>Nonparametric Tests</td>
<td>58</td>
</tr>
<tr>
<td>Partial Correlations</td>
<td>59</td>
</tr>
<tr>
<td>Analysis of Variance</td>
<td>59</td>
</tr>
<tr>
<td>Regression Analysis</td>
<td>64</td>
</tr>
<tr>
<td>Trend Analysis</td>
<td>71</td>
</tr>
<tr>
<td>Assumptions</td>
<td>73</td>
</tr>
<tr>
<td>V. Conclusions and Recommendations</td>
<td>86</td>
</tr>
<tr>
<td>Appendix 1 Language Spoken in the Home</td>
<td>93</td>
</tr>
<tr>
<td>References</td>
<td>95</td>
</tr>
<tr>
<td>Abstract</td>
<td>102</td>
</tr>
<tr>
<td>Autobiographical Statement</td>
<td>104</td>
</tr>
<tr>
<td></td>
<td>LIST OF TABLES</td>
</tr>
<tr>
<td>---</td>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Class Assignment to ILS by Teacher</td>
</tr>
<tr>
<td>2</td>
<td>Comparison of Course Content by Teaching Method</td>
</tr>
<tr>
<td>3</td>
<td>Zero-Order Correlation Matrix</td>
</tr>
<tr>
<td>4</td>
<td>Chi-Square Tests ITBS Split-Half Scores</td>
</tr>
<tr>
<td>5</td>
<td>Analysis of Variance by Teacher</td>
</tr>
<tr>
<td>6</td>
<td>Analysis of Variance by Hour of Day</td>
</tr>
<tr>
<td>7</td>
<td>Analysis of Variance by Sex</td>
</tr>
<tr>
<td>8</td>
<td>Factorial Analysis of Variance Hour of Day by Sex</td>
</tr>
<tr>
<td>9</td>
<td>Factorial Analysis of Variance Teacher by Sex</td>
</tr>
<tr>
<td>10</td>
<td>Regression Analysis All Variables Entered Stepwise</td>
</tr>
<tr>
<td>11</td>
<td>Regression Analysis Forced Entry of Algebra ILS Time, Previous Verbal Achievement, and Previous Mathematics Achievement</td>
</tr>
<tr>
<td>12</td>
<td>Regression Analysis Forced Entry of Total Time ILS, Previous Mathematics Achievement, and Previous Verbal Achievement</td>
</tr>
<tr>
<td>13</td>
<td>Trend Analysis of Algebra ILS Time</td>
</tr>
<tr>
<td>14</td>
<td>Trend Analysis of Total ILS Time</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

1 Hypothesized Model to Explain Algebra Achievement 37
2 Observed Model Explaining Algebra Achievement Algebra Time on ILS 54
3 Observed Model Explaining Algebra Achievement Total Time in ILS 55
4 Scatterplot of Regression Analysis for Algebra ILS Time 68
5 Scatterplot of Regression Analysis for Total ILS Time 70
6 Frequency Distribution of Previous Verbal Achievement 74
7 Frequency Distribution of Previous Mathematics Achievement 75
8 Frequency Distribution of Algebra ILS Time 76
9 Frequency Distribution of Total ILS Time 77
10 Frequency Distribution of Algebra Achievement 78
11 Scatterplot of Algebra Achievement and Previous Verbal Achievement 80
12 Scatterplot of Algebra Achievement and Previous Mathematical Achievement 81
13 Scatterplot of Algebra Achievement and Algebra ILS Time 82
14 Scatterplot of Algebra Achievement and Total ILS Time 83
15 Scatterplot of Regression Analysis Residuals for Algebra ILS Time 84
16 Scatterplot of Regression Analysis Residuals for Total ILS Time 85
Overview of Problem

Integrated Learning System (ILS) is an increasingly popular pedagogical tool that allows students to learn using a computer at an individualized rate. As availability of computers has grown over the last 30 years, so has their use as an educational tool. After several generations of educational systems, educators now have computers available to schools that can individualize and carefully monitor students' progress. These systems are quite sophisticated, offering a wide variety of subjects and levels, but are relatively expensive costing upwards of $100,000 for a system to service 30 students. Educators seem willing to fund such systems as ample research generally appears to justify their use (Knezek, 1988).

Problem Statement

Research involving the variable of time on ILS indicates that ILS users in general require less time for skill mastery (Hamilton, 1984). But, research is deficient on the effect of the role of various levels of time in ILS as it relates to student achievement when time is measured on anything but a nominal scale. Research seems to indicate a positive role for ILS (Roblyer, Castine & King, 1988, p. 131) concluding, "the results of this review have indicated that more is not necessarily better ... defining the role (of computer applications) is the task of the next decade." It is still unclear whether incremental increases in time spent on ILS result in proportionate increases in student achievement.
Roblyer also indicates that such studies generally treat the variable of computer assisted instruction as a nominal variable. Time in ILS as a ratio scale of measurement has not been investigated in its relationship to student achievement. It seems logical that increased time spent in any subject would increase achievement in that subject. However, if total time remains constant and is proportioned in varying amounts between traditional and computer assisted instruction across several different ninth grade algebra classes, what effect would be exhibited on the criterion of measured outcome achievement after one semester of instruction?

Evidence indicates the increased efficacy of ILS on student achievement. A logical deduction to explain this positive correlation is to assume a direct linear relation between time on the computer and algebra achievement. It is of interest to investigate this relation. Possibly a saturation point is reached where increased time on the computer results in decreased achievement, or perhaps a diminishing return. Integrated Learning Systems (ILS), a recent, sophisticated and comprehensive form of Computer Assisted Instruction (CAI), carefully records student use of the computer minute by minute. The advent of ILS management software enables the time variable to be analyzed using the actual minutes spent at the terminal rather than class periods, or assigned contacts per week. Some students use ILS in subjects other than in the algebra classes being studied. This time spent in other subjects should also be investigated since it may affect overall performance in ILS.

Research along these lines would enable educators to focus student learning in ILS on the most efficacious manner of time allotment. ILS,
especially in the more advanced ILS software now available, is very expensive, and valid information concerning time allotment is of great pragmatic and fiscal value. Students who benefit most from this method of learning may be allotted time in increments which produce the best results. Yet, too much ILS could quite likely result in diminished return and inefficient use of computer time for students waiting to use the system.

Significance of the Problem

The role of the ILS modules in education seems to be very important and increasing as ILS sales grew by 26% in 1989 to exceed $181 million (Mageau, 1988) in comparison to non-ILS software which experienced a 4% sales decrease in the same period. Despite the normal system price of $125,000 for a typical laboratory of 30 student work stations, sales data indicate educators are able to justify the expense by demonstrating improvements in instructional efficiency.

Much of the impetus behind ILS has been federal funding for Chapter 1 programs' need for materials to meet the needs of those students. Because of the large demand by school systems ready to spend Chapter 1 funds, many companies have concentrated product lines toward basic skills, and drill and practice routines. This has led to a criticism that average and above average students are not challenged. As money becomes available for programs other than Chapter 1, it is likely the demand for more challenging content will generate more software for the more advanced students.

With the increasing sales and use of ILS systems, these new educational technologies are likely to play a significant role in the future of education. Justification for large outlays of funds will require ample and careful research
into the specific cognitive processes responsible for the success of ILS so that users will maximize achievement gains. Much research has been carried out over the last decade, yet as CAI evolves, much of the research results are no longer valid for the more sophisticated systems presently available (Kulik & Bangert-Drowns, 1984) since newer systems offer software which includes more sound, color and animated graphic effects which increases the effectiveness of ILS.

Much research has indicated positive effects of CAI on student achievement and attitudes. Yet, some of the research results may be questioned on their validity. Is a purchaser of a $125,000 system likely to report to its constituency that the system shows no advantage over traditional methods? Bangert-Drowns, Kulik & Kulik (1985) showed that when evaluators were involved in secondary school CAI interventions, the effects were almost 80% higher than when they were not involved. Kulik, Kulik & Bangert-Drowns (1985) found the evaluator bias was almost 40% at the elementary level. An extensive survey of research on CAI was performed by Roblyer, Castine, and King (1988) which included a critical look at meta-analyses. Meta-analysis seeks to combine results of many studies which deal with a common area of research. Results are simplified into one statistic and conclusion about the effect of the variables of interest. Their research indicates that two thirds of analyses dealing with computer applications and skills show effect sizes above .25, but effects among different types of students and types of applications were not statistically different. Researchers also disagree on how to interpret significance for effect sizes. There is also a question of statistical significance as opposed to practical or fiscal significance when a decision must be made on allocation of funds.
Definition of Terms

The term Computer Assisted Instruction (CAI) is an umbrella term for any learning package students use as a method of instruction. It may refer to grade managers, practice problem sets or more complicated systems. Costs are frequently less than $100.

Integrated Learning System (ILS) is a sophisticated form of CAI. ILS's are much more sophisticated than most personal computer (PC) or other CAI systems. ILS's are mainframed computers which network to several microcomputers and usually have a computer management system which controls and keeps track of student progress. Lessons are carefully planned, sequenced, and incorporate current learning theory. Lessons often include branching, frequent feedback, and may include diagnostic software. The curriculum is large, incorporating many subject areas at all primary and secondary educational levels. Costs are substantially more, usually exceeding $100,000.

As used in this study it will refer to the system developed by WICAT Systems Inc. (from World Institute for Computer Assisted Teaching, terminology not used). The specific software used was the Algebra I course (1985), revision D (1990). WICAT rates students to complete this course after 100 hours of use. Teachers were instructed to choose specific content and sequence based on their individual class needs. Topics included: Whole Numbers and Integers, Rational Numbers, Real Numbers, Expressions and Equations, Linear Functions, Systems of Equations and Inequalities, Polynomials, Quadratic Functions, and Rational Expressions.
**Historical Perspective**

The development of modern Computer Assisted Instruction (CAI) has its earliest roots in Programmed Instruction (PI) (Price, 1989) which was based on Skinner's theories of behavior modification (Skinner, 1953). Skinner broadly defined learning as a change in behavior. Thus, an immediate reinforcement shown to modify behavior in animals was applied to people. From this general theory, the process of programmed instruction was developed in the 1950's. Programmed instruction, like CAI, divides a lesson into small parts called frames which immediately present the learner with a correct answer. The system was later made more flexible so that learners were required to take diagnostic tests for placement. If a question was answered incorrectly, the learner would be directed to some remedial lesson or be required to repeat part of the lesson. If mastery had been demonstrated in parts of the lesson, the learner would be allowed to skip that material which was previously mastered.

PI showed some early successes, but has more recently been regarded of little real advantage over traditional methods of instruction (Kulik & Bangert-Drowns, 1984). PI's limited success may be related to its tedious nature and inability to interact in a larger role with the learner. It also did not fit well into group-oriented, fixed-schedule, traditional school settings. The PI method of learning demonstrated the effectiveness of learning in small segments using Skinnerian principles of immediate reinforcement at each small step. Its lack of greater success has demonstrated a need for a more personalized experience and a more stimulating presentation.

A more comprehensive and integrated computer-based arithmetic learning system was developed by Suppes at Stanford University in the mid-1960's (Suppes & Morningstar, 1972), which was later extended to include language arts. Suppes' system, now marketed under the name Computer Curriculum
Corporation, demonstrated the value of a systematic, integrated plan for a comprehensive course in a subject with coordinated ancillary materials.

At about the same time a computer project at the University of Illinois known as PLATO used existing computer packages, but sought to enhance their efficacy by developing hardware and software systems which could be used with a wide variety of subject areas and large numbers of learners simultaneously. PLATO is also known for its innovative use of color graphics, touch sensitive screens, simulations and a higher level of computer-user interaction and control. These innovations provided the user with a more exciting experience which would be more likely to induce motivation and learning. Unfortunately, with computer technology still in its infancy, the cost prohibited its widespread adoption to most in the educational community. Despite these limitations, it became the standard from which many of the commercial systems of the 1990's have been developed.

Widespread use of computers in schools began to accelerate in the 1970's (Price, 1989). Initially, use of computers in secondary schools was largely dependent on shared computer use with large corporations or universities. Later, as relatively inexpensive personal computers began to find their way into homes, parents and educators began to perceive the potential for computers as an educational tool. This generated a rapidly increasing demand for CAI software. To meet this demand for educational software many programs were quickly developed. Computer software began to improve as journals such as *Computing Teacher, The Mathematics Teacher*, and *Educational Technology* began to evaluate new software packages. While it became clear that computers would have a secure role in education, it also became clear that they would not diminish the role of the classroom teacher. The computer would be used as a tool as would many other classroom tools to supplement, enhance,
and remediate learning as part of an integrated learning environment. Again, the expected cognitive panacea failed to be realized, yet a role for computers in education was clear and firmly in place.

The modern CAI systems began in the early 1980's. With a realization that educational value of software varies greatly, state agencies in California, Texas, and Minnesota, as well as the educational journals just noted, began to critically review and make recommendations for computer software. The subsequent awareness of potential buyers forced greater competition among developers of software and mediated great improvements in educational software. This second-generation of computer software increasingly involved interests of major textbook publishers in the 1980's. The larger resources and capabilities enhanced further the development of computers in education.

The most sophisticated CAI systems, known as integrated learning systems (ILS), began to emerge in the early 1980's. A traditional ILS setting consists of a computer laboratory setting with 15 to 30 micro computers connected to a large, hard drive file server which guides individual student access to the ILS software. Students generally visit this laboratory one or more times per week from their regular classes. ILS software is usually controlled by an aid-technician who performs certain managerial functions such as booting the system daily, generating printouts of progress, and adding or dropping students from the system. The process is further enhanced through a software management system which closely monitors individual student progress, lesson by lesson, and records time and achievement scores on completed lessons. This allows the teacher to more closely monitor the progress of individual students, or entire classes through customized printouts. These large systems are designed to more efficiently enhance student time with ILS through diagnostic pretests, careful articulation of course sequences, more
individualization, and they can more carefully correlate software to major textbooks.

A more extensive variation to the traditional ILS system, known as a distributed ILS, connects the main frame file server to multiple work stations, and may provide a variety of functions as a school-wide computer. The mainframe may be connected to several classrooms, each of which is equipped with several microcomputers and a teacher work station allowing the teacher access to all student records. The system may also be connected to CD-ROM based reference materials in a library or media center where students can access tools such as word processors on the file server. The system may also be connected to the school district's central computers to access student records.

A newly emerging concept in ILS known as intelligent computer assisted instruction (ICAI), or sometimes intelligent tutoring systems (ITS), may be defined as any computer program which uses artificial intelligence to help a person learn. Such a system may use probing questions to evaluate students for conceptual misunderstanding, then adjust teaching accordingly. The system may also observe performance during the learning process and provide advice on how to perform better to accomplish the task objective. These self-contained systems control the content as well as the mode of the instruction. The computer individualizes the lesson presentation according to the correctness of the learner's responses, rather than merely repeating the material. The ICAI systems are still being developed with over 20 available by 1988 (Knezek, 1988). Most ICAI systems are in science and mathematics whose subject matter is more easily defined. ICAI use has been impaired by: 1) requirement for powerful and expensive computers; 2) learning theories which do not yet adequately specify how individuals best learn; 3) limited numbers of
researchers concentrating on ICAI; and 4) a time/effort requirement far in excess of that needed for traditional ILS. As understanding of cognition increases and more powerful computers become increasingly less expensive, we can expect interest in such systems to accelerate.
CHAPTER II
REVIEW OF LITERATURE

**Meta-analysis**

The literature for CAI is abundant with over 6,000 articles in the ERIC files alone, making a summary of relevant articles difficult. Meta-analysis has aided in trying to ascertain a valid assessment of the true value of the many aspects of CAI, and how CAI appears to affect student achievement in a variety of situations. Meta-analyses performed by researchers such as Walberg and Kulik have provided insight into the overwhelming number of CAI studies related to improvement of student achievement.

In comparing CAI to traditional instruction, Walberg synthesized 16 studies and reports that CAI in general raises outcome measures with an effect size of .42 (standard deviations), which placed average CAI students at the 66th percentile of the control group distribution (Walberg, 1987). Other analyses have demonstrated similar, positive, overall effects for CAI (Kulik, 1983; Hativa & Shorer, 1989; Kulik & Bangert-Drowns, 1984), but note that the specific effects varied according to the design of the study and the type of publication in which the results were reported (Kulik & Kulik, 1987). Researchers reported an overall effect size of .51 when *different* teachers taught the CAI portion of the study. However, when the *same* teacher taught both versions, the effect size was reduced to .13 (Salomon & Gardner, 1986).

Meta-analyses for various types of learners indicated that lower achievers received more benefit from CAI than higher achievers, that effect size diminished from elementary levels at 0.4 to 0.3 in high school to 0.1 in college,
and that short-term studies showed greater effects than did long-term studies, which indicated a possible effect of novelty. Studies before 1970 indicated lower effect sizes (.27) than did studies published between 1976 and 1980 (.46), which was presumed to be associated with higher quality software (Kulik & Bangert-Drowns, 1984). Kulik and Bangert-Drowns also indicated that CAI with an effect size of approximately .4 was generally a great improvement over its predecessors, programmed instruction and individualized instruction, both with effect sizes of .1. In a meta-analysis by Niemiec and Walberg (1985) greater effect was also noted in the primary grades. Boys appeared to reap greater benefits than girls, but no relationship was found between year of study and effect size. These findings indicated that not only is the effect of CAI strong, but that it is robust over a variety of situations.

**Integrated Learning Systems**

The research on Integrated Learning Systems (ILS) form of CAI reflects the results of CAI in general (Seamen & McCallister, 1988; Alifrangis, 1990; Resta & Ross, 1986). ILS' tend to be more sophisticated, with diagnostic tools, integrated curricula, comprehensive student tracking systems to monitor student progress and are backed by companies which offer frequent updates. In a search of the literature it is apparent that much of the ILS research is referenced as CAI research. To further complicate the issue, ILS has also been used to refer to Intelligent Learning System (Christensen, 1986) and is used in ERIC files as Integrated Library System. Generally the literature uses the terms CAI and CBI (Computer Based Instruction) interchangeably. However, the latter often includes CD ROM (Computer Disk, Read Only Memory), and laser disk technologies. It also usually allows for branching of lessons.
Benefits of Active Visual Presentation

Researchers offer several explanations for the success of CAI. Walberg (1990) indicated that the impact of CAI on learning has already been substantial and credited success since, "simulations and games, with or without computer implementation, require active, specific responses from learners and may strike a balance between vicarious book learning and the dynamic, complicated, and competitive 'real world'." (p. 475) Methods of integrating current learning theory have been described (Jensen, 1985). Evidence of the effect of active as opposed to passive viewing has been demonstrated on algebra word problems (Reed, 1985). Rieber (1990) demonstrated a decreasing effect among three decreasing levels of the activity variable from animated graphics, to static graphics, to no graphics in fourth and fifth graders learning science. He crossed these three levels of graphics with three levels of practice: 1) behavioral, with questions and answers, 2) cognitive, with structured simulation, and 3) no practice, to check for possible interaction effects. The results supported Reed's conclusions that animated graphics yielded significantly better results than either static graphics or no graphics. Secondly, behavioral practice was only effective when it contained animated graphics. Thirdly, cognitive practice was shown to generally be superior to other practice conditions and did not depend on visual elaboration. Rieber concluded that the animated presentations can only promote learning under certain conditions. It was most successful in the design of cognitively based practice activities. Activities dealing with motion such as a demonstration of trajectory were shown to be especially beneficial. However, animation in other support activities such as practice was also shown to benefit from animated graphics.

These studies were made on subject matter that was well suited to visual presentation. Reed's work on algebra word problems used visual simulations
such as points moving at various speeds or vessels filling at different rates. The use of graphics for more abstract concepts which lend themselves less easily to animated graphics remain untested. Much of first year algebra dealt with such concepts as combination of like terms, polynomial factoring, associative and commutative properties, rational and irrational numbers, which are less adaptable to graphics. Nevertheless, graphics used with these objectives is still conceivable. Even the static graphics were shown to be superior to no graphics and probably explain one aspect of the apparent success of CAI.

Effects of Personality Traits

It must be cautioned that evidence of these effects may also be attributed to the novelty of the situation or other reasons. Saloman and Gardner (1986) cautioned against placing too much emphasis on successes of the new medium. They note preliminary jubilation with early research on television later resulted in disappointment. They stress that differences caused by variations among individuals resulted in varying outcome effects. The results cancelled one another out when averaged across individuals, ages, cultures, or contexts. They stress that studies into the effects of CAI should carefully consider an individual's specific traits and past experiences in relation to how these variables will affect outcomes. Different backgrounds are likely to elicit different degrees of learning, as well as different kinds of learning.

An example of the importance of inherent personality traits was shown in research examining intrinsic versus extrinsic motivation profiles in fourth through sixth grade arithmetic classes. Students showing traits of intrinsic motivation performed better using CAI than did extrinsically motivated students with differences as high as one standard deviation among the fourth graders (Mevarech,1988). If the student's personal background and interests can be
integrated in the cognitive process, significantly higher achievement scores can be expected, and attitudes will improve (Anand & Ross, 1987).

Internal personality traits have also been studied in their relationship to mathematics achievement in CAI. A MANOVA analysis using previous achievement and time on task as predictor variables studied the relationship of personality traits and their ability to predict mathematics achievement. Fourth graders (n=300) in six schools used CAI for 15 minutes each day with regular instruction. Personality traits examined were motivation level, preference toward learning alone or in groups, and preference toward visual or tactal learning. CAI groups performed significantly higher in math, but no significant effect was noted for specific learning styles or combinations of learning styles. This lack of effect for learning and processing styles was also demonstrated with (n=44) fourth and fifth graders (Sullivan, 1989), although the superiority of effect for the ILS system was again indicated. These studies indicated an effect of learning styles in upper elementary school did not mediate learning in CAI. Any differences that might exist are apparently overshadowed by other variance. The problem of properly identifying and categorizing learning can lead to unreliability. Children at this age may not have firmly fixed learning styles, leading to further unreliability. A dissertation study of effects of feedback in CAI on 74 junior college students' learning factoring did show a significant effect of learning style (Kislik, 1987). The subjects were classified into two levels of the learning process as either verbal or figural. A significant interaction effect was noted for two groups. Subjects showing significantly higher achievement were those subjects who were classified as figural learners who also received knowledge of correctness feedback which branched them to similar problems, and subjects classified as dominant verbal learners who also received feedback in the form of knowledge of correctness with explanation of
error. Such crossed interaction may explain the lack of significance in earlier studies and supports the contention that personality traits should be considered when prescribing feedback strategies inherent in modern ILS systems.

Future work in this area with more powerful assessment tools and larger sample sizes may indicate greater need to match learning style with ILS lesson presentation. However, the evidence suggests that at present the evaluation and integration of learning style to CAI instruction is unclear and will not be considered in this study.

Effects of Student Feedback

All modern ILS systems offer some form of student feedback. Substantial work was done on the effectiveness of this computer feedback on the ability of the student versus the computer to control learning pace. If performed wisely, a student should be able to set the learning pace by choosing when to move ahead in the lesson or avoid unnecessary repetition of skills. The ability to self-regulate was also shown to be the "best predictor of academic performance on all outcome measures" (Pinrich & DeGroot, 1990, p. 38). In practice, students may attempt to avoid reading or skip through lessons if they are perceived as boring or otherwise distasteful. In a study of reading achievement (n=140), ninth to twelfth graders were given various computer options while reading and answering questions on a computer-provided text (Tobias, 1987). Results of the MANOVA analysis indicated that those subjects with the mandatory review treatment outperformed others on text relevant to adjunct questions. This mandatory group was also shown to review more sentences overall. Compared to those subjects in voluntary settings, the mandatory review group would be forced to increase time required to complete a lesson. Self-reports also indicated the subjects' reading strategies to be unrelated to the strategies
actually used. This indicated these high school students had ineffective self-assessments of their reading and were unaware of the proper strategies to employ. The ability to read on one's own is important to success in the ILS setting. Much of the work is individualized, requiring each student to read and follow the directions on his or her own. It also brings out the question of students' abilities to self-assess learning in nonreading areas such as algebra. This implies that frequent feedback and mandatory review may provide the best method of enhancing algebra achievement.

Most studies concerning feedback showed a beneficial effect for conveying information to the learner on achievement and progress. Meisberger (1985) found that 27 emotionally disturbed adolescents who received a continuous display of their mathematics achievement scores attempted more work and demonstrated significantly higher accuracy than when no feedback statements were provided. However, the rate of the number of problems attempted per minute was greatest when no feedback statements were received. The net effect of time on task in general was not significant. A similar study of 70 undergraduate students receiving basic mathematics review in CAI showed that subjects who had received feedback on their achievement reported significantly (p=.007) more review behaviors than had students in control groups (Anderson, 1985). These results were consistent with the Tobias study which indicated students did not accurately assess their own achievement. When allowed, they tended to move at a faster but less accurate pace when not told their work was unsuccessful. By simply displaying the achievement score, the student was forced to consider its relevance and consequently resulted in the student's slowing down and performing at a more accurate, albeit slower, pace.

Goetzfried and Hannafin (1985) studied the effects of three specific types of feedback control strategies on the learning behavior of 47 remedial seventh
grade mathematics students. In the first method, *adaptive control*, the computer branched students for reteaching or more examples depending on accuracy of responses during the lesson. In this mode students had no control over pace or amount of teaching and could advance only when they provided correct responses and demonstrated mastery. The second strategy, *learner control with advisement*, offered continuous advise on progress toward objectives, but permitted the learner to determine whether or not the lesson should be retaught, or further practiced. Advice was given on whether or not the lesson was mastered, but the choice to go on was left to the learner. In the third control strategy, *linear control*, the learner was provided only with a sequence of instruction used in the other strategies. In this last strategy no external advice was given and the choice to review or proceed was left completely up to the learner. The student was not required to respond to given questions, but correct solutions were provided in the next frame. To proceed to the next lesson the student was required only to complete the present lesson.

The results of this study concurred with earlier studies indicating speed to decrease with degree of computer control from .70 to .51 to .36 concepts per minute (Ragosta, 1992). They reported no significant differences among the three groups, indicating time can be saved by allowing students to choose their own pace. They concluded that although linear control took less time for younger, less experienced students who are less effective decision makers, these students did need help in decision making about progress and additional instruction.

This conclusion was supported by a study of (n=98) eighth grade science students (Kinzie, et al. 1988). When given limited control over the CAI learning pace they demonstrated they needed significantly less time to achieve approximately the same performance objectives as students in computer
controlled practice. Reading was shown to be the only significant predictor to time of completion. Learner control students practiced only 37% of review items compared with 100% in the computer controlled group, and performed better on the posttest. Thus, learner control indicated it to be a more efficient method of achieving the same criteria.

There appears to exist a partial contradiction in these studies of effect of learner versus computer control. As just noted, learners who are allowed to proceed at their preferred pace appeared to be more efficient while achieving at equal or higher levels. Other studies which controlled student learning, using methods such as displaying achievement scores, forced students to spend more time on the lessons. These studies indicated this method of encouraging review are more efficient, because this forced review resulted in higher achievement. This apparent higher achievement likely occurs because of evidence which indicated students are unable to independently assess their own achievement status on CAI and proceeded before successful mastery had been achieved.

This contradiction was likely a result of variations in study design, methodology, sampling and controls. If students are forced to repeatedly practice skills already mastered, they may experience boredom and will likely achieve no better at the expense of greater time than students who are challenged, but allowed to make the mature decision to proceed if they validly perceive mastery of the skill. However, less mature decision makers may, if allowed, proceed through lessons not mastered if they have no indication their work does not merit advancement. It is also noted that levels of control and feedback varied among the studies. Studies with greatest learner control emphasized greater efficiency of speed, while studies with greatest computer control emphasized efficiency of higher achievement. It would appear
researchers found the effect which they were seeking. This indicates the possibility of a researcher bias caused by inconsistent control of variables in study designs. Additionally, the studies varied vastly in age and ability levels of subjects as well as the content and method of presentation of subject matter.

The evidence presented here suggests time benefits can sometimes be expected from allowing some student choice as to whether or not to proceed, but in other settings increased achievement can be gained by requiring mastery of content before allowing the learner to proceed. CAI can produce efficient learning both in time and achievement depending on the learner characteristics within a particular setting. Of interest is the nature of the specific factors affecting these variations.

**Effects of the Order of Presentation**

Educators may also be interested in whether CAI should precede traditional instruction for initial lesson presentation, or should be used as a practice tool to solidify concepts already presented in traditional ways. This relationship of order of presentation of traditional mathematics instruction to mathematics mastery learning in CAI was examined in a study of 117 eighth-grade mathematics students (Dalton & Hannafin, 1988). Evidence indicated that in mastery learning, performance was consistently highest when computer instruction and traditional instruction were altered in initial instruction versus remediation. This study indicated no main effect difference of traditional mathematics instruction versus CAI, but the significance of this interaction indicates the importance of combining traditional learning with CAI in mastery learning in a complementary manner in the preliminary and remedial modes regardless of which method was used initially. Reinforcement by computer was shown to be helpful among ninth grade students (Hannafin, 1987) in the form of
cues alerting the student's cognitive process to the type of information it was about to receive. The order of presentation appeared not to be as critical as the reinforcement and integration of the CAI curriculum to the regular classroom curriculum. This reinforcement and integration appeared to be important between CAI and traditional instruction as well as within the lesson itself in the form of cues.

The research on current psychological theory indicates many possible explanations why CAI and ILS' may offer advantages to traditional classroom instruction alone. These modern computer technologies are capable of integrating much of the current learning theory on a very personal format providing much more frequent and individualized feedback, while requiring much more individual interaction with the user. These technologies may act directly on the learner's achievement, or indirectly by increasing motivation, or by more efficiently utilizing the learner's time on task.

**Time on Task**

Evidence indicates increased time on task results in increased achievement. More importantly, it is the engaged time which appears to explain the advantage CAI has over traditional instruction. In CAI, evidence of elementary and secondary students indicated a high correlation of student engaged time and achievement with gains in learning among 43% of students (Walker, 1985). Unlike traditional classroom instruction, the use of the computer requires constant student interaction and the attention of the student user. The ability to individualize and pace individuals is more likely to keep the learner engaged in the learning process. Research among 173 seventh graders in science and English classes indicated a Pearson correlation of .32 to .36 for self-regulated learning components (Pintrich & DeGroot, 1990). The ability to self-regulate
appears to act through enhanced engagement of the learner on the learning task (Kinzie, Sullivan & Berdel, 1988). Practicing items was shown to account for 79% of the controlled score variance in CAI and appeared to be an unquestionable aid to the learner (Hannafin, 1987). Children in the third through sixth grades generally had higher grades when they believed their grades were caused by internal and controllable causes. Engagement acted as a mediator between perceived control and actual accomplishments. The correlation of engagement with mathematics grades was reported at .47 and with mathematics achievement at .40 (Skinner, Wellborn & Connell, 1990).

**Fisher's Model of Academic Learning Time (ALT)**

A model for Academic Learning Time (ALT) developed by Fisher, Berliner, Marliave, Cahen & Dishaw (1980) to explain academic achievement in reading and mathematics has many implications for ILS. Their Beginning Teacher Evaluation Study (BTES) followed two cohorts (n=261) of 2nd and 5th grade students and 46 teachers for one school year. Using ethnographic methods, objective observation and multiple linear regression analysis, they were able to use firsthand observations to elicit the specific behaviors exhibited by students while they were learning (or not learning). They used these observations to examine the direct effect student engagement or time on task had on achievement test scores. Their model of learning indicated that achievement test scores were not a direct measure of learning itself. Achievement scores were affected by both student aptitudes and the classroom learning process. Student aptitudes also affected achievement scores both directly and indirectly through classroom learning behaviors. Finally, the classroom learning was affected by classroom instructional processes and environment, which could include ILS. Thus, the key component of the model and the variable of interest
in their study was the actual observed behaviors of the students in the
instructional setting and their effect on resulting achievement.

Classroom learning is dependent on "allocated time". They defined this as
the upper limit on the time available during school hours for the student to work
on a topic as a continuous block or several segments. However, a smaller
subset of this allocated time described as "engaged time" is the part of allocated
time during which the student is paying attention and actively involved in the
learning activity. Measured achievement outcomes are thus not simply
dependent upon allocated "time on task" alone, but more closely on "engaged
time". This "engaged time" concept is possibly responsible for whatever
successes are noted in ILS learning. Allocated time in traditional class settings
was reported by Fisher et al. to have resulted in average engagement rates of
about 50% in mathematics and reading. However, some classes exhibited
engagement rates approaching 90%. Thus, although both situations allocated
the same amount of time to subject matter, one class may have devoted almost
twice as much time to actual learning than the other.

In an ILS setting learners were more likely to be engaged than in a
traditional setting (Latham & Stoddard, 1986; Levin Glass & Meister, 1987).
Traditional settings typically have one teacher instructing classes while
attempting to capture and direct the thoughts of many pupils. The pupils in turn
may not have to produce any immediately measurable product. However, in a
modern ILS setting with a student-computer ratio of 1:1, constant feedback is
provided, and all activity is recorded on the ILS manager. Reed (1988)
demonstrated with 180 undergraduate students that active participation in CAI
graphics showed significant superior achievement in algebra word problems
over passive viewing. A disengaged student at a computer terminal is thus
more noticeable.
The Fisher et al. study also reported a significant role for the relationship of level of student success on task with measured achievement outcomes. They identified three levels of on task success. High success was indicated when the learner demonstrated a good grasp of the subject matter with only occasional errors. Low success was noted when the learner demonstrated general lack of understanding with a correct response rate indistinguishable from a chance rate. A medium success rate filled the middle area indicated by partial understanding with some correct responses, but with enough errors to limit understanding. Fisher's et al. investigation of levels of success indicated that the more time that mathematics is practiced with high success the more positive the student behavior. Much practice with high success lead not only to higher achievements at the end of the study, but better retention over the summer and more positive attitudes toward school. Conversely, the greater the portion of time spent on activities with low success, the lower the achievement. This critical portion of engaged learning time spent at the high success level was termed *Academic Learning Time* (ALT). Thus, although allocated and engaged time were both positively associated with achievement, ALT is the time variable which is most clearly able to predict and explain achievement variance.

Several reasons for the apparent importance of ALT were also indicted by the study. First, the accuracy of the teacher's diagnostic ability to assess and predict student skill levels was positively associated with student success. In an ILS setting diagnostic and proper assignment of lessons is often carefully regulated by a computer-administered diagnostic test.

Related to proper diagnosis, there was a positive relationship noted between proper prescription of appropriate tasks and student achievement. Some ILS' automatically place learners in appropriate lessons based on their diagnostic test results. In some settings the prescription is made by the
classroom teacher. Lessons can be tailored to carefully dovetail and support the traditional classroom work. In either case, progress was carefully and individually regulated by the computer management system at the student's own pace. ILS's typically force notification and intervention by the teacher or technician if a student typically scores low on a lesson so that remediation or reassignment can quickly be facilitated.

A third finding was that more academic feedback to the student from the instructor was associated with higher levels of achievement. In traditional group settings the teacher has little opportunity for individual interaction, which may partially explain the effectiveness of group work such as cooperative learning situations. ILS now are equipped to provide frequent and effective feedback as well as support activities when they are needed. Each answer is instantly checked and the student's score and relevant encouragement are displayed. Fisher et al. indicate this frequent feedback lead to higher rates of engagement and ultimately to higher achievement.

Finally, more carefully structured lessons and careful explanation to direct on task behaviors were associated with higher achievement. ILS software is extremely well structured, albeit flexible. Lessons are carefully planned and attempt to integrate current learning theory. Learners are given frequent and detailed suggestions on how to solve problems. Help is frequently available whenever the learner requests clarification.

The Relation Between ALT and ILS

The ALT model provides many corollaries to ILS learning. Students receiving ILS instruction may demonstrate higher achievement over students in traditional settings if their use of time shows a stronger penchant to the subject matter. The ALS model can informally be stated as: measured achievement =
(ratio of engaged time) x (ratio of time at high success activities). These two predictors of achievement were in turn demonstrated to be influenced by variables such as 1) ability of teachers to diagnose student skill levels, 2) ability of teachers to properly prescribe appropriate tasks, 3) substantive and frequent teacher-student interaction, 4) frequent academic feedback, 5) the degree to which the lessons are well structured, 6) the ability to stringently limit low success activities, and 7) allocated time. These traits are all inherent in modern ILS with the possible exception of allocated time. With so close a relationship of ILS to the ALS model, the effect of the allocated time variable is of distinct interest.

Although the Fisher et al. study was intended as a general model for learning achievement, its close relationship to CAI has been supported by other research. Bright (1983) described this close relationship and how CAI is able to increase engaged time by eliminating wasted time for low success activities. In a study comparing relative engaged time in computer and noncomputer environments, Latham and Stoddard (1986) reported English classes to be on task 95.1% of the time in the computer environment, but only 58% of the time in noncomputer environment. Teachers were also shown to be more involved with students who were using computers. Seifert and Beck (1983) specifically studied the relationship of engaged and disengaged time and its relationship with algebra achievement among 60 high school students. In behaviors generally related to the daily learning objectives they found Pearson correlations with achievement of .452 to .465 for on task behaviors and -.40 to -.50 for disengaged behavior. These independent studies indicate further empirical support for valid application of the ALT model to CAI in general and especially to ILS.
Other studies have indicated a general positive correlation between CAI time on task and academic achievement. Gourgey et al. (1984) reported correlations of .70 for time on CAI and mathematics performance for 152 2nd through 8th graders in mathematics. Mevarech (1986) reported correlations of time at CAI and achievement at .36, .21, and .25 (p<.05) for 2nd, 3rd, and 4th graders exposed to two, 20-minute arithmetic sessions per week. The study also reported significant improvement in achievement if an optional third session is added for 2nd and 3rd graders only.

Kulik et al. (1985) performed a meta-analysis of specific features affecting CAI success including the relationship of time on task variables to achievement effects in 28 CAI studies. They indicated that in the typical situation students received 26 hours of CAI: 15 minutes per day, four days a week for 26 weeks. They indicated an effect size of .4 standard deviations, which would raise achievement from the 50th to the 68th percentile. Welch et al. (1982) reported in a study of (n=2216) 17 year-olds that 34% of all achievement in mathematics could be attributed to course and exposure. Rigg (1990) reported time in CAI to be a significant predictor of achievement in grade five computation. Achievement scores were shown to increase as time on CAI increased. Similar results were demonstrated by Baron, Abrami & Wasserman (1986) with 256 fifth and sixth graders in vocabulary achievement in CAI.

**ILS's Greater Efficiency**

Another approach to the time-achievement relationship is to indicate the amount of time it takes to achieve a particular criterion while using CAI. CAI also appeared to decrease the amount of time needed to master learning objectives (Kulik, 1983; Hannafin, 1987). This may be due to the ability of CAI to enforce the control of content sequence and display time. Learning time was
shown to diminish when the display time on the computer was controlled by the computer, based on previously established individual needs (Tennyson, Park & Christensen, 1985). Groups whose exposure was limited and controlled required fewer examples and took fewer time outs. According to Bloom's theory on the mastery learning concept of time, learning can be enhanced by enhancing the ratio of on task learning to off task learning (Bloom, 1976). By controlling exposure time, "down time" is reduced. This may be especially important for slow learners who may be less skilled in time allotment associated with learning new material. Thus, instead of raising achievement, it frees more class time for other objectives. In a meta-analysis Kulik et al. (1980) found a significant savings in time investment for eight studies of this type. Average time saved was indicated to be 64.3%. While not increasing absolute time on task, this does indicate increased efficiency with CAI.

These studies indicated time was an important variable in several ways. Time must obviously be invested in course content to expect any achievement. By devoting more time to a subject it is logical to expect more achievement. The research showed that the increase in achievement is dependent upon the portion of this allocated time that students actually devoted their thoughts and actions to the class lesson. The research here indicated that when working with CAI, students spent significantly more of the allocated time on their lesson than did students in more traditional settings. The ALT theory further indicated that achievement was increased not only by the amount of allocated time or engaged time on task, but rather by the portion of the engaged time that students spent at tasks where they experience high success. Thus, ILS lends itself well to the ALS theory. Not only does ILS increase the ratio of time on task, but with frequent academic feedback, constant student interaction, individualized lessons, readily available help and encouragement, elimination
of low success activities, and stress on high success activities, the ILS is able to engage the learner in a more meaningful and perhaps efficient manner. Time on task studies indicated this to be the case, but most were done at the elementary level and used only two or three levels of CAI time, and frequently did not consider important mitigating variables such as previous achievement.

**Previous Verbal and Mathematics Achievement and Sex**

The effects of CAI on student achievement must take into account previous achievement. Previous mathematics achievement was demonstrated to be the best predictor of future performance (Hativa & Shorer, 1989; Bloiland & Michael, 1984). Correlations between reading achievement and mathematics achievement have been reported in the range of .62 to .81 in a longitudinal study of 4th through 6th graders (Griswold, 1984; Marsh, 1986). In a study of (n=233) seventh graders, Iowa Test of Basic Skills (ITBS) scores from the seventh grade in mathematics had correlations ranging from .68 to .81 (p<.0005) with end-of-year achievement as measured by the test publisher's final examination (Hill, 1989). The ITBS was demonstrated in regression analysis to be the best predictor, surpassing previous grades, teacher recommendations, gender, or local school district test. Mevarech (1991) claimed as much as 88% of achievement outcome of mathematics instruction can be predicted by a prior achievement test written for that purpose.

Several studies have also indicated a significant interaction of sex with verbal achievement and mathematical achievement. Evidence has shown that males generally score higher on math achievement tests than females (Tsai & Walberg, 1983). It was demonstrated by a five-year longitudinal study (Benbow & Stanley, 1982) that males show a significant inherent advantage over females in ability to reason and achieve in mathematics. Abilities were shown to
develop more rapidly in males than in females, but no difference in attitudes toward mathematics was found between the sexes. In a study involving 739 males and 758 females in Irish schools Bolger and Kellaghan (1990) found boys had higher achievement in mathematics than girls. In a meta-analysis of 72 studies looking at variables involved in CAI instruction at all grade levels, Lee (1990) found that males demonstrated higher achievement than females in CAI instruction and generally showed more positive attitudes towards mathematics instruction.

Evidence of general male superiority in mathematics has not gone unchallenged. Sometimes study results can be internally conflicting in this regard. Bridgeman and Wendler (1991) showed males on nine college campuses to have higher average SAT scores by one third a standard deviation, but grades were observed to be equal in the groups. Becker (1990) indicates no differences between sexes with respect to mathematical ability. Evidence also suggested that differences in mathematics achievement could at least in part be traced to stereotypes that were perpetuated (Jacobs & Eccles, 1985), or that gender played only a small role (Marsh, 1989), or that gender differences were not significant (Mevarech & Rich, 1985). An interaction was found between gender and racial-ethnic background favoring girls' achievement in Hawaiian schools (Brandon, Newton & Hammond, 1987). Students in grades 4, 6, 8, and 10 were compared for mathematics achievement and reasoning skills and were classified ethnically as Japanese, Caucasian, Filipino-American, or Hawaiian. The study showed 1) these girls had higher overall achievement levels than boys, 2) boys were highest in mathematical reasoning, girls were highest in computation, 3) high-achieving girls out performed high-achieving boys, 4) sex differences favoring girls among Caucasians were less than differences favoring girls in other groups, 5)
differences appeared as early as grade four and increased with age to percentile differences ranging from 1.12 to .48 favoring females. This study indicated the possibility of sex differences varying among different racial-ethnic groups and indicated females can have an academic advantage in mathematics in some cases.

The Effects of Personal Attitudes and Social Influences

The gender differences in mathematics achievement may not be genetic, but could also be explained by differences in attitude and self-concept. In an attempt to explain these apparent contradictions, evidence indicated that attitudes toward mathematics achievement differed across the sexes (Ethington & Wolfe, 1986). In particular, they demonstrated that mathematics ability and attitudes toward mathematics had stronger effects on mathematics achievement for men than for women. Staz (1988) found 80 female beginning algebra students to have significantly lower expectations about their grades than boys ($r = -.24$) and tended to dislike algebra more $r = -.25$ and found algebra to be more difficult $r = -.28$. When achievement on pretest, posttest and grades were compared in males and females, correlations were all less than .1 and not statistically significant. A similar study (Stipek & Gralinski, 1991) of 473 eight to fourteen-year-olds also showed girls to have a lower self-rated ability than boys and they expected to do poorer. Girls were more likely than boys to attribute failure to lower ability and felt effort was not an important factor in determining success. Girls were shown to take less pride in their work and were more likely to be concerned about social approval for their mathematics achievement. These attitudes indicated that any gender differences may very well be explained as differences in attitude, expectations, and self concept.
Toci and Engelhard (1991) investigated mathematics achievement, gender differences, parental support, and attitudes toward mathematics in 3,846 American and 3,528 Thai thirteen-year-olds. The study used a multivariate general linear model with various measures of attitudes toward math as criterion variables and mathematics achievement; parental support and gender were used as predictor variables. In both countries achievement, parental support, and gender were significant predictors of attitudes toward achievement for these subjects. The largest gender difference found was that mathematics was viewed as a male-dominated domain. This result remained even after controlling for achievement and parental support. Thus, reasons for female lower mathematics self-concept may stem from parental socialization indicating mathematics to be a male domain.

These studies seem to indicate that male superiority in mathematics achievement appears to be largely due to enculturization and social stereotypes. While these studies showed great gender differences in attitudes towards mathematics, actual achievements are frequently attenuated or even reversed in some situations. Variations across cultures indicated different gender effects. The effect of gender on mathematics is inconclusive but appears to vary with circumstance and is at least partially a product of existing social attitudes.

Marsh's Self Concept Model

Marsh (1986) developed an Internal/External Frame of Reference Model (I/E model) that utilizes differences in self-concept in mathematics to explain the action of self-concept on math achievement. In his model he notes that math and verbal self concepts are nearly uncorrelated. The self-concept is, however, composed of two parts; external and internal. External self-concept results from
the students' comparison of their own abilities with those of other students in their own frame of reference. They then use these external relativistic impressions as one basis of their own academic self-concept in math and verbal abilities. It is also assumed this process is used by external observers (researchers) to infer the self-concept of someone else.

In internal comparisons the students compare their self-perceived math ability with their self-perceived verbal ability and use this internal, relativistic impression as a second basis of their self-concept in each of the two areas. This process is not used by external observers when asked to infer self-concepts, so these inferred self-concepts will differ systematically from self-reported self-concepts, hence the discrepancy reported in earlier research.

In a study testing equivalence of models for math and verbal achievement across sexes (Byrne & Shavelson, 1987) it was shown that males had general self-concepts which correlate higher with math self-concept than English self-concept. In females the opposite was true. This supports findings that females have higher English self-concepts and lower math self-concepts than boys. Even when males have lower math grades, they maintain a higher self-perceived success in the subject and tend to perpetuate societal sex-role stereotype.

In a related study (Ethington & Wolfe, 1986) using a three-year cohort analysis of (n=16,555) high school students found females to be less likely to change their attitude toward math ability than males. This inflexibility results in a relative lack of achievement for females. Also, it was shown that math ability and attitudes toward math had stronger effects on math achievement for males than females.

Skaalvik and Rankin (1990) directly tested Marsh's I/E model, but found no general support. Their evidence indicated no support for the expected near-
zero correlation between math and verbal self-concept. The correlation was instead a substantial .67. Also, the expected negative effect of math achievement on verbal self-concept was found to be significantly positive \( r = .34 \), although differences of correlations between the sexes were noted among other parts of the model.

There appears to be much uncertainty in the relationship of sex and math and verbal achievement. Although the nature of the interactions of these variables is unclear, their importance to one another appears to be likely in many situations and warrants further consideration.
CHAPTER III
METHODOLOGY

Design

Eight intact algebra classes from four teachers were assigned between one and four contact sessions (25 minutes each) per week in the ILS setting in the fall of 1990. This course is the first semester of a four semester sequence that completes topics typically covered in beginning algebra. The text used was the fourth edition of *Introductory Algebra One* by Russel F. Jacobs (Harcourt, Brace, and Javanovich, 1982). Trained teachers made computer assignments to classes based on the computer content which most closely followed their classroom/textbook lessons. Achievement posttest examination was taken of algebra skills learned by each subject and recorded as a dependent measure of achievement. Time spent working with the ILS was recorded in minutes by the computer management system. The computer time in this study replaced rather than supplemented traditional class time. Time, the variable of interest, was then analyzed using multiple regression analysis by first removing variance for gender, and previous mathematics and verbal achievement. This study is designed to examine the effects of student time in ILS has on the achievement outcome of ninth grade algebra students.

Assignment of classes depended on availability of time in the ILS laboratory. Classes were assigned to use the ILS laboratory according to the following schedule:
Table 1

**Class Assignment to ILS by Teacher**

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Class period</th>
<th>Number of contacts per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

An effort was made wherever possible to vary numbers of contacts across teachers, and thus minimize any correlation of class period during the day with numbers of contacts. This was done since contact periods could become a source of uncontrolled systematic variance, as student attentions may dwindle late in the day.

After one semester of algebra instruction in both ILS and traditional classroom approaches, all subjects were tested to assess their algebra skills. The dependent variable of algebra achievement was then regressed on the predictor variables of prior mathematical achievement, prior verbal achievement, sex, and time on ILS as shown in the hypothesized model below:
It was hoped this model could be used to both predict and explain student achievement. The variable of time on ILS was hypothesized to significantly contribute to the regression equation when variance for the other predictor variables were removed. This regression design and model allowed all four variables to be analyzed simultaneously while controlling for interactions among them. It also allows variance to be statistically removed from algebra achievement by the previous math and verbal achievement variables, producing a less confounded portion of variance which was examined by the variable of time on ILS alone.
**Instrument**

The dependent variable, algebra achievement, was measured using the Orleans-Hanna Algebra Prognosis Test (The Psychological Corporation, Harcourt, Brace, and Javanovich, 1982). The test is a sixty item, multiple choice test having five possible answers including. The manual reports a maximum required reading level of sixth grade for the test, although it reports results averaging well below that level for many items and reading sections. (Harris and Jacobson, 1972). The algebra test manual reports internal consistency based on Kuder-Richardson Formula 20 to be .96 (SEM=3.14) for the sample used (n=2684) in the standardization program. The reliability of this algebra test with the 1968 version is .92 (SEM=0.7). Predictive validity is reported at .73 and .83 with mid-year and end-of-year algebra achievement test scores respectively, and at .72 for both mid and end-of-year algebra grades.

Item analysis reports a median point biserial Pearson correlation value of .53. This statistic indicates the Pearson correlation between scores on the full sixty-item multiple choice test and scores on the individual items. Thus, it is an index of the extent to which the individual test items discriminate among total scores at various levels on the test.

The actual test administration time is rated at 45 minutes and thus was able to be completed in a regular 55-minute class period. Algebra achievement data for students in the sample were recorded in raw score form as the total number of items correct out of a possible score of sixty.

This study seeks to determine the relative efficacy of traditional classroom/textbook instruction versus ILS algebra instruction. It is of significant interest to examine the construct validity of the algebra achievement variable as measured by the Orleans-Hanna Algebra Prognosis Test and any possible
biased relationship to the two predictor variables of the course content in the ILS, and the course content of traditional classroom instruction.

The Orleans-Hanna Algebra Prognosis Test is divided into ten sections, each with a short, instructive lesson and a test. The test consists of six problems in each of the ten sections. The problems within each section tend to increase in difficulty within a section. Each lesson consists of a short text consisting of three to six numbered steps and includes examples demonstrating the skill needed. The student is instructed to "Study this lesson and then do the test that follows." Of the ten lessons, four (lessons 1, 2, 3, and 6) are concerned with the student's substituting one or more numbers for variables in algebraic phrases of varying difficulty. Answers are given in parentheses. The simplest require only one multiplication of zero by a whole number; e.g., "If $s=0$, then $5s$ equals $(0)$, the most complex require substitution of two variables in a quadratic phrase (variables raised to the second power) and require knowledge of order of operation among exponents, multiplication, and addition; e.g., "If $p=4$ and $s=7$, then $3p^2+2s$ equals $(62)$". Of the remaining six lessons, two involve translating word questions into algebraic statements. The first such lesson (4) deals with concrete problems; e.g., "A boy is $n$ years old. His sister is four times as old. The sister's age is $(4n)$". The second lesson (8) concerns word problems deals with abstract examples and includes $>$ and $<$ symbols; e.g., "A number $r$ multiplied by itself is less than 25 ($r^2<25$)". The remaining four lessons may be described as follows: lesson 4 deals with addition and subtraction of positive and negative numbers; e.g., $(+11) + (-4)$ equals $+7$; lesson 7 deals with evaluation of "$f(y)$" statements; e.g., "If $f(y)$ equals $2y+1$ and $y=10$, then $f(y)$ equals $(21)$"; lesson 9 deals with combination of coefficients and like terms in algebraic phrases; e.g., "$4z+8z-10z$ equals $(2z)$"; lesson 10 is a review of the other nine lessons and instructs the students to "turn back to any lesson if you
need to do so." In general, the test uses 20% word problems, 40%
substitution/evaluation/order of operations, 10% "f(y)" evaluation, 10%
combination of like terms, and a 10% review of the above. It should be noted
that each lesson requires some reading as well as a willingness on the part of
the student to take the time as needed to read and understand the concept each
lesson teaches.

This measure of the dependent variable can now be compared with the
course content variables in ILS versus traditional classroom/textbook. The
algebra course under investigation uses the first seven chapters of the textbook,
Introductory Algebra One, which deals only with positive numbers. Chapter
One deals with order of operation among one digit numbers, substitution and
evaluation of expressions with one and two variables, word problems to be
solved using a given formula, and unit price comparisons. Chapter Two deals
with the identity properties in algebra of identity of 0 and 1, Commutative and
Associative properties of addition and multiplication, distributive property,
factoring, and combining of like terms by addition and subtraction. Chapter
Three is concerned with integer factors of a number, tests for divisibility of a
number by 2, 3, 4, 5, 9, and 10, prime numbers and factorization, and least
common multiple of numbers. Chapter Four deals with addition, subtraction,
multiplication, and division of fractions, including variables, and word problems
using formulas to calculate area and perimeter of triangles. Chapter Five
introduces solving equations for one variable by adding, subtracting, multiplying
or dividing, first in one-step problems, then with two and three-step problems.
Chapter Six utilizes these skills in solving word problems, some using a general
formula. The final chapter develops the concept of ratio and proportion, then
uses these skills to solve story problems, including percents. It should be noted
that specific lessons completed is up to the discretion of the individual teacher.
The Orleans-Hanna test and the Jacobs text both stress order-of-operations, combination of like terms, substitution and evaluation of open phrases, and word problems. The Orleans-Hanna test is lacking in evaluation of: unit pricing; the algebraic associative, commutative and distributive properties; factoring and the concept of prime numbers; manipulations of fractions; equation solving; and ratio and proportion. Found in the Orleans-Hanna test, but lacking in these text chapters, are the concepts of negative number addition, and evaluation of equations using f(y) notation, and translation of inequalities.

The Orleans-Hanna test should also be compared with the ILS course content. Previous research indicated achievement was most efficacious when the ILS content presented to the student is left to the discretion of the classroom teacher to be presented in the manner which most closely correlated with the traditional setting (Dalton & Hannafin, 1988). It should be noted that because of time constraints, all students were not be presented all the lessons cited here. Available topics in the ILS software package include: patterns in number tables, prime and composite numbers, number line including > and < symbols; associative, commutative, and distributive properties; identity properties of zero and one; addition and subtraction of signed numbers; multiplication and division of signed numbers; fractions, ratios and proportions, rates; comparison of fractions; word problems dealing with ratios, fractions and decimals as percents; word problems involving percent; finding greatest common factor; use greatest common factor to simplify and multiply fractions; addition of fractions using least common denominator; Pythagorean Theorem; rational versus irrational numbers; decimal and fraction conversion; simplifying expressions using order of operations; simplifying expressions using parentheses; simplifying expressions by adding and subtracting exponents; simplifying expressions using the distributive property and combining of like terms; solving
equations using one, two, and three-step problems; solving equations with variables on two sides of the equation; and solving equations with parentheses on both sides of the equation. Although this list is not exhaustive of the WICAT Algebra I course content, it represents the selections from which teachers chose. These topics are summarized in table 1 below.

Table 2
Comparison of Course Content by Teaching Method

<table>
<thead>
<tr>
<th>Orleans-Objective</th>
<th>Hanna</th>
<th>Text*</th>
<th>ILS*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substitute a number for a variable and evaluate</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Simplify expressions involving parentheses using order of operations</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Translate word problems into algebraic equalities</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Translate word problems into algebraic inequalities</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Add and subtract positive and negative numbers</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Objective</td>
<td>Orleans-Hanna</td>
<td>Text*</td>
<td>ILS*</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
<td>---------------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>Evaluate algebraic equations by substitution using f(y) notation</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combine like terms involving exponents</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Combine like terms involving variables without exponents</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Solve equations for a variable requiring 1, 2, or 3 steps</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Use a stated formula to solve problems</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Compare using unit price</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Manipulate algebraic expressions using algebra properties:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>commutative, associative, and distributive</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Factor algebraic expressions</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Objective

Review nonalgebraic fractions and percents

Solve problems using ratio and proportion

Solve word problems using ratios

Compare prime and composite numbers

Look for patterns in number tables

Solve problems using the Pythagorean Theorem

Distinguish rational and irrational numbers

Convert fractions to decimals

*Specific final lesson content is made at the discretion of the classroom teacher.
Variables

The independent variable under scrutiny, time in ILS, was measured constantly by the ILS management system without error as actual minutes using ILS rather than assigned contact periods. This method allowed more accurate measurement of individual student time on task than simply counting the potential hours assigned. This minimizes error in measurement if the time variable caused by absences or the students' being called out of class. The data collected was continuous, and of a ratio scale of measurement.

A second time variable examined total student time spent in ILS including other classes. Many students were assigned to use the ILS system from classes other than the algebra class studied here, such as reading improvement. It was of interest whether this additional time in ILS combined with the ILS in algebra affected the students' performance in the algebra portion of ILS, and thus affected the overall dependent measure of algebra achievement. Since the variance in total time in ILS was partly composed of the variance in algebra ILS, the two measures of ILS were not independent and thus had to be analyzed separately.

No algebra pretest was made, since students had no previous exposure to algebra. A multiple-choice pretest in algebra could likely have produced excessive, unwanted, error variance due to guessing among students who have had no previous algebra instruction. Several other measures of previous achievement were used instead. A strong predictor of algebra achievement is the student's prior mathematical achievement (Hativa & Shorer, 1989; Bloland & Michael, 1984). This achievement was measured twelve months prior to the experiment on the Iowa Test of Basic Skills (ITBS). The ITBS provided a measure of mathematical skill in the following areas: 1) Math Concepts, 2) Math
Computation, 3) Math Problem Solving, 4) Total Mathematics skills. Data from all scores were analyzed and only the variables with the highest zero order correlation with the dependent variable of algebra achievement were used in the analysis.

The verbal achievements of the students were analyzed in a fashion similar to that just described, using: 1) Vocabulary, 2) Reading, 3) Usage, and 4) Total Language Skills, as well as 5) Combined Score. The verbal achievement is of interest since many of the student subjects use English as a second language (see appendix 1). These students may exhibit varying levels of language proficiency which in turn may affect ability to assimilate instruction both in ILS and in the traditional classroom. Data from the ITBS were examined and those scores demonstrating the highest zero order correlation with algebra achievement were included in the analysis.

**Sample**

The 105 subjects used in the sample included all ninth grade algebra students from the middle of three achievement levels of tracking in a suburban Detroit class A high school. To be in the sample they must have had eighth grade ITBS scores available and have completed the entire 20 week treatment period on ILS. Students were placed in this level of tracking based on their ITBS scores and their eighth grade mathematics teacher's recommendation. The sample eliminated students from other grades who may have been in these classes, since they may have been repeating the course and were likely to have been older. These subjects could have produced biased data if they were included in the study sample. Thus, although the sample was somewhat purposive by ability, it was done independently of this experiment and did tend to eliminate achievement outliers in both tails of achievement distributions.
Scales of Measurement

The data from the ITBS were recorded as percentiles. As percentiles, they are ordinal in nature and would violate the requirement for regression analysis that data be at least interval. The data were thus entered as raw scores for use in the analysis.

The two scales of measure for time are both ratio and measured without significant error, since data was continuously collected by the computer manager as the ILS system was utilized.

The dependent variable, algebra achievement, as measured by the Orleans-Hanna Algebra Prognosis Test also used raw data making it a ratio scale of measure.

Data Analysis

Multiple regression analysis allowed several predictor variables to be simultaneously analyzed, while allowing for interactions among these variables, when it is expected that such intercorrelations exist. It also allowed for use of the continuous scales of measurement which is consistent with the data. Multiple regression analysis requires certain assumptions to be met for the results to be meaningful. Data for each of the variables studied were examined to assure normal distribution and homoscedasticity. The requirement for linearity was examined also, but the hypothesis considered the possibility of a nonlinear relation between time on ILS and algebra achievement.

All analyses were performed using SPSS 4.0 for the Macintosh (Macintosh, 1990). Analysis began with an examination of the variables in a zero-order-correlation matrix. This intercorrelation matrix enabled potential suppressor variables to be eliminated and avoided such problems as multicollinearity. It
permitted the assessment of unwanted systematic variance from previous achievement. Those variables indicating highest correlation with the dependent variable, algebra achievement, were used in the regression analysis. These variables were entered into the regression analysis by forced entry and changes in the R-square statistic were noted for statistical significance.

The method of forced entry was employed since it was not expected that time in ILS would be the best predictor of achievement, but it was the variable of interest. It must be remembered that in this study time on ILS supplants rather than supplements traditional class instruction. While its effect may have been statistically significant, it was not expected to have as great an effect as if it would be provided in addition to traditional class time.

In the regression analysis a primary statistic of interest was the squared multiple correlation coefficient (R-squared) whose significance was evaluated by the omnibus F-statistic. The squared multiple correlation or coefficient of determination indicates the proportion of variance of the dependent variable accounted for by the independent variables. It may also be viewed as the squared correlation of the observed algebra achievement scores with the algebra scores predicted by the regression equation. This "goodness of fit" tells how well the model actually explains the data. It also indicates whether one or more of the independent variables (beta weights) is a statistically significant predictor of the dependent variable (algebra achievement.). The test for significance of the squared multiple correlation coefficient is the F statistic. The test of this statistic depends not only on the total R-squared, but on the degrees of freedom determined by the sample size, and the number of predictor variables. The adjusted R-square statistic adjusts this optimistic value for large sample sizes and large numbers of predictor variables.
The sample used in this study was 107 subjects with three predictor variables. Since these numbers are relatively small, the adjusted R-square statistic was not expected to change radically.

Selection of the nominal alpha level is critical to interpretation of the F-statistic. Selection of this significance level, which is equal to the rate of type I error, must be weighed against the power of the statistical test for this research problem. Statistical power for a regression analysis was somewhat limited due to the modest sample size (n=107). It is also noted that very little research has been conducted into ILS time on task, when ILS supplants rather than supplements traditional classroom instruction. For these reasons a relatively high significance level of .05 was chosen for this pioneering study.

The interpretation of any statistical significance required careful interpretation. Statistical significance of the regression equation in this study did not indicate absolute efficacy of ILS but rather a rectilinear relation between supplanted ILS time with algebra achievement. Subjects could have exhibited a diminishing return or even a negative relation with high levels of ILS time. It is entirely possible that while a relationship existed, it may have been curvilinear in nature. This assessment suggested an investigation using trend analysis to examine the possibility of a curvilinear relation and to examine the nature of its form. Trend analysis seeks to find the lowest-degree polynomial that best fits the data. Each degree of polynomial is associated with one degree of freedom. The curvilinear relation was expected to be at most a second degree relation for time and would increase degrees of freedom for regression by no more than one.

Analysis of the regression equation continued with examination of the value and significance of the beta coefficients. These standardized regression coefficients may or may not have been statistically significant even if the
coefficient of determination was found to be statistically significant. This may have occurred when the standard errors for beta became relatively large if the independent variables were highly intercorrelated. Significance of a given beta coefficient would indicate its slope to significantly differ from zero in the regression equation as an aid in explaining the dependent variable, algebra achievement, while controlling for the other independent variables.

While examination of the coefficient of determination, R-square, was sufficient in predicting algebra achievement, this study was interested in whether time on ILS aids in explaining algebra achievement in terms of the independent variables. The beta weight of the time factor was of critical interest and was carefully examined. Its zero-order correlation with algebra achievement was considered along with first and second-order correlations by partialing out the variance for mathematics achievement and verbal achievement. It was noted that these partial correlations may have been higher or lower than zero-order correlations.
CHAPTER IV
RESULTS

ZERO-ORDER CORRELATIONS

Zero order correlations were first examined to determine which of the ITBS scores for verbal and math skills should be used as predictor variables in the regression equation and to avoid problems caused by potentially high correlations. Of the three ITBS verbal scores of vocabulary, reading comprehension, and usage and expression, the dependent variable, algebra achievement, correlated highest with usage & expression ($r=.3843, p<.0005$) and was not significantly correlated with the other two verbal scores. Of the three ITBS math scores, algebra achievement was statistically significantly correlated with all three ($r=.4652, r=.3161, r=.2286$) but showed the highest correlation with math concepts ($p<.0005$). These two variables of usage & expression for the construct previous verbal achievement, and math concepts for the construct previous math achievement were therefore selected for use in subsequent analyses.

Examination of the sex variable showed it was not significantly correlated with the dependent variable, algebra achievement. However, it is noteworthy that the data indicated sex was significantly correlated with two of the independent variables of 1) verbal (ITBS) achievement including usage & expression ($r=.2012, p=.040$) and with the ITBS math score of math computation ($r=.2091, p=.031$). The verbal score which was used for the subsequent regression analyses supported results of previous research indicating females score higher on verbal achievement tests than do males. All three previous ITBS mathematics achievement measures indicated females scored higher
than did their male counterparts. However, only one of the three, math computation, was statistically significant \((r=.2091, p=.031)\). It was not the ITBS variable chosen to represent the construct of previous achievement for further analysis since it explained less variance than did the math concepts variable. Also, sex was shown to significantly correlate with time using ILS for algebra instruction \((r=-.1942, p=.045)\), which indicated males spent more time in algebra ILS instruction than did their female counterparts. This effect was even more pronounced when time in ILS is added in from nonalgebra classes \((r=-.2386, p=.013)\). Hour of day was also significant \((r=-.2115, p=.029)\), which indicated males to be more prevalent in the ILS laboratory later in the school day than were females. A statistically significant correlation was also noted between hour of day and time in ILS \((r=.3388, p<.0005)\), and between teacher and hour of day \((r=-.3928, p<.0005)\).

The correlation of interest, time on ILS with algebra achievement, was shown here in zero-order correlations to not be statistically significant with either algebra ILS time \((r=.0649, p=.534)\), nor when nonalgebra ILS time was added in \((r=-.0460, p=.660)\). It is also noteworthy that all three verbal ITBS scores were significantly and negatively correlated with total time on ILS, the highest being usage & expression \((r=-.4139, p<.0005)\). This indicated students of lower verbal skills tended to spend the largest portion of combined time in ILS. A similar relationship was noted in the math ITBS score used as a predictor variable \((r=-.2379, p=.015)\), which again indicated those subjects with lowest math ITBS scores tended to spend more time using ILS. It should be noted that only 27 students in this study used the ILS outside the algebra setting. Thus, although the sample size remains 94, time data on only 27 subjects changes from the algebra ILS time value to the total ILS time value.
Consequently the correlation of these two ILS time variables was fairly high (r=.7651, p<.0005).
Figure 2

Observed Model Explaining Algebra Achievement Algebra Time on ILS

Algebra Time on ILS

Sex

Prior Math Achievement

Prior Verbal Achievement

Algebra Achievement

(.1580) N.S.
.0649 N.S.
.0746 N.S.
-.4139
.4652
.3843

partial correlations in parantheses
All correlations are significant unless otherwise noted
Figure 3

Observed Model Explaining Algebra Achievement Total Time on ILS

Total Time on ILS

Sex

Prior Math Achievement

Prior Verbal Achievement

Algebra Achievement

(.2413)

-.0460 N.S.

.1749 N.S.

-.2379

.4652

.3843

.2012

.4258

.4139

partial correlations in parentheses

All correlations are significant unless otherwise noted
Table 3

Zero-Order Correlation Matrix

VARIABLE NAMES

V1 = ID NUMBER
V2 = SEX 1=MALE 2=FEMALE
V3 = VERBAL ITBS (VOCABULARY)
V4 = VERBAL ITBS (READING COMPREHENSION)
V5 = VERBAL ITBS (USAGE & EXPRESSION)
V6 = MATH ITBS (MATH CONCEPTS)
V7 = MATH ITBS (MATH PROBLEMS)
V8 = MATH ITBS (MATH COMPUTATION)
V9 = ILS TIME ALGEBRA
V10 = TEACHER
V11 = HOUR OF DAY
V12 = MATH ACHIEVEMENT (ORLEANS-HANNA PROGNOSIS TEST)
V13 = ILS TIME NONALGEBRA
V14 = ILS TIME TOTAL (V9 + V13)
V15 = VERBAL ITBS TOTAL (V3 + V4 + V5)
V16 = MATH ITBS TOTAL (V6 + V7 + V8)
NONPARAMETRIC TESTS

Total time on ILS appeared in zero-order correlations to be closely related to the ITBS verbal and mathematics predictor scores. A chi-square test was performed to examine the possibility of regression toward the mean accounting for systematic achievement variance which might have been misinterpreted as having resulted from time on ILS. Split halves using nationally normed mean values as indicated in the ITBS test manual (Hieronymus & Hoover 1986) were used to compare numbers of students above and below the average score. Results indicated statistically significant numbers of students in the sample performing below the mean on both the ITBS verbal and mathematics sections (verbal: n=80/27 chi-square=26.252, p<.0005; mathematics: n=77/30 chi-square=20.645, p<.0005).

Table 4
Chi-Square Tests ITBS Split-Half Scores

<table>
<thead>
<tr>
<th>Category</th>
<th>Observed</th>
<th>Expected</th>
<th>Chi-Square</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Verbal</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>80</td>
<td>53.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>27</td>
<td>53.5</td>
<td>26.252</td>
<td>&lt;.0005</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mathematics</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>77</td>
<td>53.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>30</td>
<td>53.5</td>
<td>20.645</td>
<td>&lt;.0005</td>
</tr>
</tbody>
</table>
Partial Correlations

Although the zero-order correlation of algebra achievement and ILS time did not demonstrate statistical significance, the partial correlation of algebra achievement and total ILS time was statistically significant ($r = .2413$, $p = .011$) when variance for previous mathematics and verbal achievement were controlled. A similar examination of the partial correlation between algebra achievement and algebra ILS time was found not to be statistically significant ($r = .1580$, $p = .069$).

Analysis of Variance

One way analysis of variance was performed on each of three variables: teacher, hour of day, and sex, with algebra achievement as the dependent variable. Algebra achievement was shown not to significantly differ among teachers ($F = 1.5315$, $p = .2118$, $n = 94$). Similarly, hour of day was found not to be statistically significant ($F = 1.7588$, $p = .1442$, $n = 94$), nor was sex found to be statistically significant ($F = .5153$, $p = .4747$, $n = 94$). The three ANOVA analyses were repeated using the covariates of previous algebra and verbal achievement which in correlation analysis had demonstrated statistical significance. These covariate analyses also showed no statistical significance.
Table 5
ANALYSIS OF VARIANCE by Teacher

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>D.F.</th>
<th>SUM OF SQUARES</th>
<th>MEAN SQUARES</th>
<th>F RATIO</th>
<th>PROB</th>
</tr>
</thead>
<tbody>
<tr>
<td>BETWEEN GROUPS</td>
<td>3</td>
<td>558.6615</td>
<td>186.2205</td>
<td>1.5315</td>
<td>.2118</td>
</tr>
<tr>
<td>WITHIN GROUPS</td>
<td>90</td>
<td>10943.5513</td>
<td>121.5950</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>93</td>
<td>11502.2128</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6
ANALYSIS OF VARIANCE by Hour of Day

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>D.F.</th>
<th>SUM OF SQUARES</th>
<th>MEAN SQUARES</th>
<th>F RATIO</th>
<th>PROB</th>
</tr>
</thead>
<tbody>
<tr>
<td>BETWEEN GROUPS</td>
<td>4</td>
<td>842.6331</td>
<td>210.6583</td>
<td>1.7588</td>
<td>.1442</td>
</tr>
<tr>
<td>WITHIN GROUPS</td>
<td>89</td>
<td>10659.5797</td>
<td>119.7706</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>93</td>
<td>11502.2128</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7
ANALYSIS OF VARIANCE by Sex

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>D.F.</th>
<th>SUM OF SQUARES</th>
<th>MEAN SQUARES</th>
<th>F RATIO</th>
<th>PROB</th>
</tr>
</thead>
<tbody>
<tr>
<td>BETWEEN GROUPS</td>
<td>1</td>
<td>64.0649</td>
<td>64.0649</td>
<td>.5153</td>
<td>.4747</td>
</tr>
<tr>
<td>WITHIN GROUPS</td>
<td>92</td>
<td>11438.1478</td>
<td>124.3277</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>93</td>
<td>11502.2128</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Factorial analysis of variance using the variables teacher, hour of day, and sex using algebra achievement as the dependent variable was not possible since teacher by hour of day results in several empty cells. Thus, two
way factorial ANOVAs were performed. Neither analysis, hour of day by sex 
\(F=0.002, p=1.00\), nor teacher by sex \(F=0.041, p=0.989\), showed statistical 
significance for effects of interactions. The analysis was repeated using the 
statistically significant covariates of previous mathematics and verbal 
achievement, but again neither hour of day by sex \(F=0.603, p=0.662\), nor teacher 
by sex \(F=0.354, p=0.786\) indicated statistical significance.
Table 8

Factorial Analysis of Variance Hour of Day by Sex

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effects</td>
<td>947.687</td>
<td>5</td>
<td>189.537</td>
<td>1.509</td>
<td>.196</td>
</tr>
<tr>
<td>Sex</td>
<td>105.054</td>
<td>1</td>
<td>105.054</td>
<td>.836</td>
<td>.363</td>
</tr>
<tr>
<td>Hour of Day</td>
<td>883.622</td>
<td>4</td>
<td>220.905</td>
<td>1.758</td>
<td>.145</td>
</tr>
<tr>
<td>2-Way Interactions</td>
<td>.992</td>
<td>4</td>
<td>.248</td>
<td>.002</td>
<td>1.00</td>
</tr>
<tr>
<td>Explained</td>
<td>948.679</td>
<td>9</td>
<td>105.409</td>
<td>.839</td>
<td>.582</td>
</tr>
<tr>
<td>Residual</td>
<td>10553.534</td>
<td>84</td>
<td>125.637</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>11502.213</td>
<td>93</td>
<td>123.680</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 9

Factorial Analysis of Variance Teacher by Sex

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effects</td>
<td>680.408</td>
<td>4</td>
<td>170.102</td>
<td>1.354</td>
<td>.257</td>
</tr>
<tr>
<td>Sex</td>
<td>121.747</td>
<td>1</td>
<td>121.747</td>
<td>.969</td>
<td>.328</td>
</tr>
<tr>
<td>Teacher</td>
<td>616.343</td>
<td>3</td>
<td>205.448</td>
<td>1.635</td>
<td>.187</td>
</tr>
<tr>
<td>2-Way Interactions</td>
<td>15.449</td>
<td>3</td>
<td>5.150</td>
<td>.041</td>
<td>.989</td>
</tr>
<tr>
<td>Explained</td>
<td>695.857</td>
<td>7</td>
<td>99.408</td>
<td>.791</td>
<td>.597</td>
</tr>
<tr>
<td>Residual</td>
<td>10806.355</td>
<td>86</td>
<td></td>
<td>125.655</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>11502.213</td>
<td>93</td>
<td></td>
<td>123.680</td>
<td></td>
</tr>
</tbody>
</table>
Regression Analysis

Regression analysis was performed regressing the dependent variable, algebra achievement, on the four predictor variables of 1) sex, 2) previous mathematics achievement, 3) previous verbal achievement, and 4) the variable of interest, time in ILS. An initial regression analysis using all the variables and the stepwise method allowed three variables to enter the regression equation. Statistical significance was found for the following variables: 1) previous verbal achievement (beta=.404231), 2) previous mathematics achievement (beta=.335658), and 3) total time in ILS (beta=.234408) with multiple R=.55570, and R square=.30880.

Table 10

Regression Analysis All Variables Entered Stepwise

| Multiple R | 0.55570 |
| R Square   | 0.30880 |
| Adjusted R Square | 0.28524 |
| Standard Error     | 9.34933 |

Analysis of Variance

<table>
<thead>
<tr>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3436.48339</td>
<td>1145.49446</td>
</tr>
<tr>
<td>88</td>
<td>7692.07095</td>
<td>87.40990</td>
</tr>
</tbody>
</table>

F = 13.10486  Signif F = .0000
---------- Variables in the Equation ----------

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>Beta</th>
<th>T</th>
<th>Sig T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math</td>
<td>.931901</td>
<td>.223487</td>
<td>.404231</td>
<td>4.170</td>
<td>.0001</td>
</tr>
<tr>
<td>Verbal</td>
<td>.640899</td>
<td>.198913</td>
<td>.335658</td>
<td>3.222</td>
<td>.0018</td>
</tr>
<tr>
<td>Total ILS Time</td>
<td>.009353</td>
<td>.004010</td>
<td>.234408</td>
<td>2.333</td>
<td>.0220</td>
</tr>
<tr>
<td>(Constant)</td>
<td>.765226</td>
<td>6.292881</td>
<td>.122</td>
<td>.9035</td>
<td></td>
</tr>
</tbody>
</table>

---------- Variables not in the Equation ----------

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta In</th>
<th>Partial</th>
<th>Min Toler</th>
<th>T</th>
<th>Sig T</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEX</td>
<td>-.022737</td>
<td>-.026485</td>
<td>.711466</td>
<td>-.247</td>
<td>.8054</td>
</tr>
<tr>
<td>VOCAB</td>
<td>-.102269</td>
<td>-.109788</td>
<td>.652110</td>
<td>-1.030</td>
<td>.3057</td>
</tr>
<tr>
<td>READ</td>
<td>-.144778</td>
<td>-.134037</td>
<td>.592443</td>
<td>-1.262</td>
<td>.2105</td>
</tr>
<tr>
<td>MATH PROB SOLV</td>
<td>.020965</td>
<td>.020723</td>
<td>.673249</td>
<td>.193</td>
<td>.8471</td>
</tr>
<tr>
<td>MATH COMPUTE</td>
<td>.093560</td>
<td>.107119</td>
<td>.723462</td>
<td>1.005</td>
<td>.3177</td>
</tr>
<tr>
<td>ILS ALG TIME</td>
<td>-.087983</td>
<td>-.062547</td>
<td>.274835</td>
<td>-.585</td>
<td>.5604</td>
</tr>
<tr>
<td>TEACHER</td>
<td>-.100675</td>
<td>-.113915</td>
<td>.691384</td>
<td>-1.069</td>
<td>.2878</td>
</tr>
<tr>
<td>HOUR OF DAY</td>
<td>.069639</td>
<td>.078072</td>
<td>.689961</td>
<td>.730</td>
<td>.4671</td>
</tr>
<tr>
<td>ILS TIME NONALG</td>
<td>.086005</td>
<td>.062547</td>
<td>.365571</td>
<td>.585</td>
<td>.5604</td>
</tr>
<tr>
<td>VERBAL TOTAL</td>
<td>-.205534</td>
<td>-.145187</td>
<td>.344902</td>
<td>-1.369</td>
<td>.1746</td>
</tr>
<tr>
<td>MATH TOTAL</td>
<td>.132955</td>
<td>.090534</td>
<td>.315112</td>
<td>.848</td>
<td>.3988</td>
</tr>
</tbody>
</table>
The stepwise regression analysis was followed by a forced entry regression analysis method forcing time in ILS into the regression equation following the statistically significant variables of previous mathematics and verbal achievement. Since sex showed a nonsignificant zero-order correlation with the dependent variable \((r=.0746, p=.475)\), further forced regressions were performed using only the three predictor variables 1) time on ILS, 2) previous verbal achievement, and 3) previous mathematics achievement. Results for algebra ILS time indicate its contribution to the regression equation not to be significant with a change in R square of .01831 at significance level of .1370. When the analysis was repeated using total ILS time, the results indicated its contribution to explanation of algebra achievement to be statistically significant with a change in R square of .04273 at a significance level of .0220.
Table 11

Regression Analysis. Forced Entry of Algebra ILS Time, Previous Verbal Achievement, and Previous Mathematics Achievement

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Multiple R</td>
<td>.53327</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R Square</td>
<td>.28438</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adjusted R Square</td>
<td>.25998</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standard Error</td>
<td>9.51307</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis of Variance

<table>
<thead>
<tr>
<th></th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>3</td>
<td>3164.68910</td>
<td>1054.89637</td>
<td>11.6561*</td>
</tr>
<tr>
<td>Residual</td>
<td>88</td>
<td>7963.86524</td>
<td>90.49847</td>
<td></td>
</tr>
</tbody>
</table>

*p<.05

----------- Variables in the Equation -----------

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>Beta</th>
<th>T</th>
<th>Sig T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math Ach</td>
<td>.890358</td>
<td>.226134</td>
<td>.386211</td>
<td>3.937</td>
<td>.0002</td>
</tr>
<tr>
<td>Verb Ach</td>
<td>.464674</td>
<td>.186509</td>
<td>.243363</td>
<td>2.491</td>
<td>.0146</td>
</tr>
<tr>
<td>ILS Time</td>
<td>.007884</td>
<td>.005254</td>
<td>.136103</td>
<td>1.501</td>
<td>.1370</td>
</tr>
<tr>
<td>(Constant)</td>
<td>6.778079</td>
<td>5.383817</td>
<td></td>
<td>1.259</td>
<td>.2114</td>
</tr>
</tbody>
</table>
Figure 4

Scatterplot of Regression for Algebra ILS Time
Table 12

Regression Analysis Forced Entry of Total Time ILS, Previous Mathematics Achievement, and Previous Verbal Achievement.

| Multiple R | .55570 |
| R Square   | .30880 |
| Adjusted R Square | .28524 |
| Standard Error | 9.34933 |

Analysis of Variance

<table>
<thead>
<tr>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>3</td>
<td>3436.48339</td>
</tr>
<tr>
<td>Residual</td>
<td>88</td>
<td>7692.0705</td>
</tr>
</tbody>
</table>

F = 13.10486  Signif F < .00005

------------------------ Variables in the Equation ------------------------

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>Beta</th>
<th>T</th>
<th>Sig T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math Ach</td>
<td>.931901</td>
<td>.223487</td>
<td>.404231</td>
<td>4.170</td>
<td>.0001</td>
</tr>
<tr>
<td>Verb Ach</td>
<td>.640899</td>
<td>.198913</td>
<td>.335658</td>
<td>3.222</td>
<td>.0018</td>
</tr>
<tr>
<td>ILS Tot Time</td>
<td>.009353</td>
<td>.004010</td>
<td>.234408</td>
<td>2.333</td>
<td>.0220</td>
</tr>
<tr>
<td>(Constant)</td>
<td>.765226</td>
<td>6.292881</td>
<td>.122</td>
<td>.9035</td>
<td></td>
</tr>
</tbody>
</table>
Figure 5

Scatterplot of Regression Analysis for Total ILS Time
**Trend Analysis**

An attempt was made to further refine the regression model by examining the residuals for the possibility of a curvilinear relationship using trend analysis. The data for algebra ILS time indicated no statistical significance toward a curvilinear relationship ($F=.0148$, $p=.9090$). Similarly the parallel analysis for total ILS time indicated a similar lack of statistical significance ($F=.6147$, $p=.4902$).

Table 13

**Trend Analysis of Algebra ILS Time**

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>SUM OF D.F.</th>
<th>MEAN SQUARES</th>
<th>MEAN SQUARES</th>
<th>F RATIO</th>
<th>F PROB.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BETWEEN GROUPS</td>
<td>87</td>
<td>77.0409</td>
<td>.8855</td>
<td>.2962</td>
<td>.9871</td>
</tr>
<tr>
<td>WEIGHTED LINEAR TERM</td>
<td>1</td>
<td>2.1951</td>
<td>2.1951</td>
<td>.7342</td>
<td>.4398</td>
</tr>
<tr>
<td>DEVIATION FROM LINEAR</td>
<td>86</td>
<td>74.8458</td>
<td>.8703</td>
<td>.2911</td>
<td>.9882</td>
</tr>
<tr>
<td>WEIGHTED QUAD. TERM</td>
<td>1</td>
<td>.0443</td>
<td>.0443</td>
<td>.0148</td>
<td>.9090</td>
</tr>
<tr>
<td>DEVIATION FROM QUAD.</td>
<td>85</td>
<td>74.8015</td>
<td>.8800</td>
<td>.2943</td>
<td>.9874</td>
</tr>
<tr>
<td>WITHIN GROUPS</td>
<td>4</td>
<td>11.9591</td>
<td>2.9898</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>91</td>
<td>89.0000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 14

Trend Analysis of Total ILS Time

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>D.F.</th>
<th>SUM OF SQUARES</th>
<th>MEAN SQUARES</th>
<th>RATIO</th>
<th>PROB.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BETWEEN GROUPS</td>
<td>88</td>
<td>82.2252</td>
<td>0.9344</td>
<td>0.4138</td>
<td>0.9283</td>
</tr>
<tr>
<td>WEIGHTED LINEAR TERM</td>
<td>1</td>
<td>4.0304</td>
<td>4.0304</td>
<td>1.7847</td>
<td>0.2739</td>
</tr>
<tr>
<td>DEVIATION FROM LINEAR</td>
<td>87</td>
<td>78.1947</td>
<td>0.8988</td>
<td>0.3980</td>
<td>0.9362</td>
</tr>
<tr>
<td>WEIGHTED QUAD. TERM</td>
<td>1</td>
<td>1.3881</td>
<td>1.3881</td>
<td>0.6147</td>
<td>0.4902</td>
</tr>
<tr>
<td>DEVIATION FROM QUAD.</td>
<td>86</td>
<td>76.8066</td>
<td>0.8931</td>
<td>0.3955</td>
<td>0.9374</td>
</tr>
<tr>
<td>WITHIN GROUPS</td>
<td>3</td>
<td>6.7748</td>
<td>2.2583</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>91</td>
<td>89.0000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Assumptions

Regression analysis requires that certain assumptions be fulfilled to make the analysis meaningful. Although regression analysis is generally regarded as robust toward minor assumption violations, any serious deviations from expected values can make interpretation of the results suspect. An examination of the data to check that assumptions for regression are not violated shows little general cause for concern. Kurtosis values from the frequency distribution histograms range from -.935 to -.131 as reported in SPSS 4.0 for the Macintosh (1990). Similarly, skewness values range in absolute value from .131 to the greatest deviation from zero of .454 for previous mathematics achievement and -.416 for the dependent variable, algebra achievement. Although neither deviates from zero by the guideline value of .5, their proximity should be noted. The dependent variable, algebra achievement, tends to be skewed towards the left indicating a tendency toward an abnormally high number of subjects receiving high posttest scores. The opposite tendency is exhibited in the previous math achievement variable where the preponderance of subjects appear to have received low scores. This tendency has already been noted in the chi-square test.

Another feature which seems to appear in figures 6 and 8 for previous verbal achievement and algebra ILS time is some evidence for a bimodal distribution. This may be an artifact of the choice of frequency intervals, especially since it disappears in figure 9 for total ILS time, which changes time values for only 27 subjects. Yet, the possibility remains of the existence of two populations of subjects for these variables.
Figure 6

Frequency Distribution of Previous Verbal Achievement

![Bar chart showing the frequency distribution of ITBSRaw Scores with specific values for Kurtosis and Skewness]

Kurtosis = -0.626
Skewness = 0.131
Figure 7

*Frequency Distribution of Previous Mathematics Achievement*

Kurtosis = -0.131
Skewness = 0.454
Figure 8
Frequency Distribution of Algebra ILS Time

Kurtosis = -.935
Skewness = .162
Figure 9

Frequency Distribution of Total ILS

Time

Kurtosis = -.704
Skewness = .343
Figure 10

Frequency Distribution of Algebra Achievement

Kurtosis = -0.654
Skewness = -0.416
Scatterplots in figures 11 and 12 indicate the correlation of the dependent variable, algebra achievement with the ITBS previous verbal and mathematics raw scores. Distributions about the regression line indicate fairly regular normal distributions indicating homoscedasticity.
Figure 11

Scatterplot of Algebra Achievement and Previous Verbal Achievement
Figure 12

Scatterplot of Algebra Achievement and Previous Mathematical Achievement
Scatterplots in figures 13 and 14 compare the dependent variable, algebra achievement with algebra and total ILS time. They indicate a broad general scattering demonstrating general lack of significant relationship \((r=.0649, p=.534)\) with algebra ILS time and \((r=-.0460, p=.660)\) with total time on ILS.

Figure 13

*Scatterplot of Algebra Achievement and Algebra ILS Time*
Figure 14

Scatterplot of Algebra Achievement and Total ILS Time

Figures 15 and 16 indicate a plot of residuals along the regression line. Again the distribution across the regression line appears to be normal and stable at both high and low values of the variables indicating homoscedasticity.
Figure 15

Scatterplot of Regression Analysis Residuals for Algebra ILS
Time

Studentized Residual

Algebra Achievement
Figure 16

Scatterplot of Regression Analysis Residuals for Total ILS Time
CHAPTER V

CONCLUSIONS and RECOMMENDATIONS

Interpretation of the intercorrelation matrix supports previous research indicating a significant correlation between measures on the ITBS of the constructs of previous mathematics and previous verbal achievement with values as high as .49. The correlations with the dependent variable, ninth grade algebra achievement, indicate the value in using these predictor variables in the analysis since they are able to statistically account for substantial amounts of systematic variance in obtaining a clearer picture of the manner in which time in ILS functions. Indeed, neither algebra time in ILS nor total time in ILS, by themselves, was significantly correlated with algebra achievement in zero-order correlations. Evidence of a statistically significant correlation only appeared after removal of variance by these two predictor variables.

In this study the data on sex differences supports the contention that females achieve higher than their male counterparts on verbal achievement tests reaching significance in two of three subtests. However, the data also indicates females also surpass males in achievement on mathematics achievement ITBS, reaching statistical significance in one of the three mathematics subtests. Males were also shown to be spending significantly more time in the ILS setting both in algebra and from other classes and appeared more frequently later in the day. Since sex appeared not to be a significant variable to algebra achievement in the ANOVA analysis, second order effects of sex by hour of day seem unlikely. A 2 by 7 factorial examination of sex and time of day indicated no second order interaction.
In the study design, classes of subjects were scheduled by hour of day in as diverse a fashion as possible to avoid hour of day by achievement correlations. This was done to prevent fatigue or other events of maturation to result in significant systematic effects on learning and subsequent achievement. Despite this effort, the positive correlation between hour of day and algebra time in CAI is significant. Its effect on achievement is not likely strong, since the correlation of hour of day and achievement appears not to be significant. It is also likely this apparent correlation is a result of the single teacher who was uniquely assigned four contacts per week resulting in the largest portion of allotted time. This is noted in the high negative correlation of teacher and hour of day.

Evidence of a relationship of time in ILS and algebra achievement is noted in examination of partial correlations and in the regression analyses. When variance is removed from algebra achievement, time spent in ILS does demonstrate a positive linear relationship to ninth grade algebra achievement. These relationships depicted graphically in figures 4 and 5 depict a general rectilinear trend with no indication of attenuation at higher levels in either total or algebra ILS time. It is noteworthy that the relationship appears to exist in total CAI time but does not reach significance for algebra CAI time. It should also be noted that only 27 subjects had increased times in the total ILS time variable. That is, only 27 of the subjects in this study had ILS class time in nonalgebra subjects such as reading. This subtle difference implies little difference in the two parallel studies of ILS time.

Several interpretations are possible. One interpretation could be that the range of time in ILS was much more limited in algebra with a maximum value of 837 minutes, but in total ILS increases to 1220 minutes, an increase of 45.8%. A true linear relation may not express itself when its values are limited
over a relatively small range. Only when the same relationship examined over a wider range can the true nature of the relationship be ascertained. Had it been possible to increase the range of algebra ILS time, it is plausible a significant relationship may have been demonstrated. Similarly, with more power from a larger sample size (N>91), significance may also have been demonstrated.

Another interpretation is that as students spend more time in the ILS laboratory, they become increasingly acclimated to and comfortable with the ILS equipment. With this adjustment, confidence and efficiency in working with the computer would increase, resulting in greater achievement scores.

Both interpretations imply that higher levels of ILS time might result in even greater increases in achievement. Results of the trend analysis indicate no evidence of a curvilinear relation in the range of time used in this experiment. This tends to dispel the theory that students might tire of working at the computer and would result in diminished levels of achievement for the time studied here of four 25-minute contacts in algebra and two additional contacts from other classes. Further research might clarify the role of ILS if subjects are assigned to even higher levels of computer time.

Results of the chi-square test of split halves indicates equal numbers of high and low achievers on the ITBS mathematics and verbal subtests are not represented in the sample. This raises the argument that apparent ILS achievement may in fact be caused by disproportionate numbers of low achievers simply regressing toward the natural mean. This effect is somewhat attenuated since split halves used in the chi-square test were not the unit of analysis in the regression analyses, which compares all subjects in a continuous rather than discreet manner.
The rectilinear relationship noted between time on ILS and algebra achievement implies no limit to the amount of algebra achievement gain possible through increased time on ILS, yet research (Dalton & Hannafin, 1988) indicated the importance of some traditional classroom instruction. Thus, of the five 55-minute periods of algebra instruction available per week, no upper limit for ILS instruction was witnessed at the level of four 25-minute sessions or roughly 20% of the allotted class time. Any diminished return or loss of effectiveness must appear at some higher level. The implication of significance for total ILS time is that the limit may extend as high as 46% above the four contacts (1220 minutes in total ILS time versus 837 minutes in algebra ILS time) or approximately six such contacts per week.

The lack of significance for the correlation of sex and algebra achievement may not be as surprising as the apparently superior prior achievement exhibited by females on the ITBS. By removing this variance of superior female achievement, it might seem some of the variables indicating significant zero order correlations may have interacted to enhance the significance of the partial correlation of ILS time and algebra achievement. These interactions include: 1) males with increased time in ILS, 2) males increased presence later in the day, 3) time on ILS increased later in the day. Other research (Niemiec & Walberg, 1985) noticed males to reap greater benefits from ILS. Yet none of these indicated statistical significance in the regression analysis. Thus, although these and other factors may have significant zero-order correlations, they did not significantly effect the results. Evidence here tends to support that contention, although not in a significant way.

The ILS form of CAI appears to be a valuable tool as part of a complete curriculum by this research and by previous studies. This study indicates that
students with the greatest time invested in ILS in place of traditional classroom
instruction produced the greatest levels of achievement when previous math
and verbal achievement were controlled. The indication of no upper limit to the
four contacts per week indicates students do not tire of the ILS laboratory. With
as much as six 25-minute contacts per week, they continue to make gains in
achievement proportionate to the amount of time spent in the ILS setting. The
preponderance of lower ability students receiving the largest amount of time in
the ILS setting reinforces this relationship, especially because of the research
indicating lower ability students reap the greatest benefits (Kulik & Kulik, 1987).

The rectilinear relationship of ILS learning and ninth grade algebra
achievement indicates achievement can be enhanced by maximizing time
spent in the ILS laboratory. The maximum amount of time allotted of four 25-
minute contacts per week in algebra and two contacts per week in other classes
was the maximum time available to the researcher due to scheduling
constraints in the ILS laboratory. Attitudes have been demonstrated to be very
positive for ILS use (Mys & Petrie, 1989) by both teachers and students.
Demand for ILS time is great and was not met by the available supply. There
appears to be a need for expanded usage of the ILS beyond four 25-minute
contacts per week and warrants consideration of use in more subject areas.

Increased use should not be limited to low ability students. Evidence
indicates honor mathematics students also derive greater gains than students in
regular classes (Parker, 1989). The individualized and self-paced format also
allows advanced students to progress at higher rates than their classmates for a
more flexible, open-ended method of lesson presentation.

The increase in world technology is reflected in the design and
application of ILS. These latest advances can now be integrated into ILS
packages along with sound, high-resolution color graphics, animation,
sophisticated diagnostics, branching of lessons, and remediation based on constant feedback, making ILS an increasingly attractive tool for education.

This attraction does have a price. ILS costs over $100,000. The high cost seems to be justified by their growing popularity. The relative cost effectiveness was not part of this study, but has been a concern of others (Davis & Greenfield, 1987; Levin et al., 1986). The resolution of this fiscal concern may in part depend on the resolve of governments to invest money for these new technologies.

Some see the advent of CAI technology as the beginning of a completely new era in education (Kulik & Bangert-Drowns, 1984). The first revolution began when societies began to institutionalize education by removing responsibilities from parents in an attempt to make it uniform and more efficient. The second revolution was the use of the written word as a tool for recording and conveying information between generations. The third was the intervention of the printing press which allowed mass dissemination of information. Whether or not instructional technologies will have an equally profound effect on education to be considered a fourth revolution remains to be seen. Clearly, technology has affected many facets of society and daily life already. It seems likely such technologies will also impact education in an equally profound manner. However, this should in no way diminish the role of the classroom teacher. A need for personal interaction is evident. What is apparent is a need for teachers to be trained, and be aware of the contents of the ILS curricula they are using and be willing to carefully correlate and integrate ILS curricula with the course objectives. America appears to be searching, sometimes almost desperately, for methods of dealing with perceived lack of competitiveness in the world, because of inept skills of its graduates. ILS offer a viable method of addressing this dilemma. Some talk of a standardized national curriculum
could lead to clearer objectives that could be more easily addressed by companies creating ILS packages. It is even conceivable that the federal government could invest its resources into supporting development of ILS software to promote attainment of its goals. By promoting such technologies, costs would diminish and availability would increase. As a world leader in this technology, America should consider its potential and profit from its increased use.
Appendix 1

Language Spoken in the Home
REFERENCES


Seaman, D. F. & McCallister, J. M. (1988). An evaluation of computer assisted instructional systems used to deliver literacy services for J. T. P. A. participants at Houston Community College. Texas A & M University, Texas


SPSS 4.0 for the Macintosh. (1990). Spss Inc. Chicago IL.


ABSTRACT

THE EFFECTS OF AN INTEGRATED LEARNING SYSTEM USING INCREMENTAL TIME ALLOTMENTS ON NINTH GRADE ALGEBRA ACHIEVEMENT

by

ROBERT CHARLES WEST

May 1992

Advisor: Donald Marcotte
Major: Evaluation and Research
Degree: Doctor of Philosophy

Integrated Learning Systems (ILS) have become increasingly prevalent and sophisticated in the last decade. Research has demonstrated a general achievement advantage in ILS's over more traditional methods, but scant data are available on the effect of variation of ILS's time on student achievement. This study sample consists of 107 ninth grade average achievers, many of whom speak English as a second language. Subjects were assigned to between one and four 25-minute contacts per week resulting in between 15 and 1220 minutes of total ILS contact time over one semester in the fall of 1990. ILS time for algebra instruction and combined time including nonalgebra classes were analyzed in parallel studies. The study used multiple regression analysis to test for a relationship between time at ILS and algebra achievement using previous verbal achievement and previous mathematics achievement as other predictor variables. Sex was also examined but found not to be a significant predictor variable for algebra achievement. Time in ILS was found to be a statistically significant predictor of algebra achievement only when total ILS time from all classes was analyzed. The results indicate a limit for effective
advantage for ILS is not limited to four contacts per week. Since significance was found for total ILS time but not algebra ILS time, there may exist a need for a wide range of scores for statistical significance. It may also indicate evidence of increasing efficiency as students become more familiar with the ILS system.
Robert Charles West has resided in Southeastern Michigan most of his life. Undergraduate studies at the University of Michigan in Ann Arbor were completed in 1974 when a Bachelor of Science degree was conferred, majoring in zoology and German. Undergraduate studies included a year of foreign study at the University of Munich (Ludwig-Maximillian Universitaet) 1972-1973. Mr West began studies towards his Master of Arts in Teaching in 1974 at Wayne State University, completing the program in 1977. In 1975 he accepted a position in Dearborn Public Schools teaching mathematics and science. In 1978 he was granted a leave of absence to accept a position in Berlin, Germany at the John F. Kennedy Gemeinschaft Schule where he also taught secondary mathematics and science. In 1980, Mr. West returned to his position in Dearborn Public Schools where he now is a teacher of high school mathematics as well as a member of the district's K-12 Assessment Committee and the Magnet Programs Committee. Mr. West is an adjunct faculty member at Wayne State University and has done research for the University's School of Community Medicine in the Personal Injury Research Center in 1988, as well as Oakland Community College, office of research in 1990. Mr. West currently resides in Dearborn, Michigan with his wife and four children.