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Title: Effects of Individualized Examples and Personalized Contexts in Computer-Based Adaptive Teaching of Algebra Word Problems

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The purpose of the present investigation was to develop an adaptive teaching model for an interactive computer-assisted instruction (CAI) program and to evaluate the effectiveness of the implementation of individualized examples or individualized examples in personalized contexts. Translating word problems into equations provided the context for the CAI investigation.

Four classes from two middle schools in Oregon constituted the population from which subjects were selected. Subjects completed a biographical questionnaire and a pretest prior to treatment. During the 45-minute treatment, subjects received a CAI lesson and practice problems following each example. On the day following the treatment, a posttest and a reaction questionnaire were administered to measure the main effects of these approaches.

Three parallel CAI versions were developed as treatments for algebra word problem translations: 1) abstract, 2) individualized, and 3) individualized/personalized. In the abstract version, example and practice problems were presented without the involvement of specific learner interests or experiences. In the individualized version, example and practice problems were selected and constructed based upon learner interests and experiences. In the individualized/personalized version, exam-

ple and practice problems were selected and constructed based upon learner interests and experiences, in addition to which personal biographical information was embedded into the contexts of problems.

With respect to learning outcomes, the three different examples and contexts produced equivalent performances, with no significant posttest performance differences. Effects for individualized examples and personalized contexts for interactive CAI were not significant. The treatment effects for the practice performance were significant. Individualized and individualized/personalized groups answered significantly more practice problems correctly than the abstract group. Differences between the individualized and the individualized/personalized groups were not significant.

For the reactions to the treatments, two out of eight items elicited significantly different responses. When asked whether "the word problems were interesting," subjects in the individualized/personalized group were more in agreement than the individualized and abstract groups. When asked whether "the word problems helped him/her understand the problem-solving situations," subjects in the individualized/personalized group were more in agreement than subjects in either the abstract or the individualized groups. For the open-ended questions, subjects stated that they were more serious and task-oriented when using the interactive CAI program.

Effects of Individualized Examples and Personalized Contexts In Computer-Based Adaptive Teaching of Algebra Word Problems

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Chapter 1

INTRODUCTION

Adapting the curriculum to learners' individual differences is a concern for teachers at all levels (Belland, Taylor, Canelos, Dwyer, & Baker, 1985). An important potential advantage of computer-assisted instruction (CAI) over traditional teaching methodologies lies in its powerful capabilities for adapting to individuals (Hannafin, 1984; Tennyson & Park, 1984).

Commonly, instructional strategies for the adaptation of programs to accommodate learners' individual differences have been through the control of: 1) concept sequences, 2) example sequences, 3) the number of concepts to be learned, 4) the forms of the concepts, 5) the number of examples, 6) difficulty levels, 7) display time intervals, 8) pacing, 9) branching, and 10) the feedback formats. Three types of control strategies have been developed, namely, learner-control, program-control, and adaptive-control. These strategies are based on either the learners' prior knowledge identified through pretesting (Goetzfried & Hannafin, 1985; Tennyson & Rothen, 1977), on-task responses (Park & Tennyson, 1980; Tennyson & Park, 1984; Tennyson & Rothen, 1977; Tennyson, Park, & Christensen, 1985), grade point average (GPA) (Gay, 1986; Sales & Williams, 1988), SAT scores (Schloss, Sindelar, Cartwright, & Smith, 1988), learning styles (Sales & Williams, 1988), or cognitive styles (Carrier, Davidson, & Williams, 1985; Robert & Park, 1984). These strategies are used to systematically generate and deliver instructional resources in a manner that would be either difficult or impractical to achieve in textbook or lecture presentations (Ross & Anand, 1987).

Hall (1983) asserted that the kinds of examples and questions presented to learners are the critical variables in the design of computer-based education (CBE) lessons. He also advocated that the use of examples and/or questions in CAI required the manipulation of the context to engage deep cognitive processes. A number of prior studies have also shown the learning context has a strong influence on students' performances (Bower, 1981; Branford & McCarrell, 1974; Di Vesta & Ross, 1979; Mayer, 1975, 1977, 1980, 1982; Schwaneflugel & Shoben, 1983), especially for novice problem-solvers (Chi, Glaser, & Rees, 1982; Owen & Sweller, 1985).

Anand and Ross (1987) developed a computer model designed to increase the flexibility and practicality of adaptive strategies by: a) constructing personalized contexts for each student, b) orienting the contexts to everyday interests and background variables, and c) automating the tasks of lesson preparation and administration. In tests of this personalized model against abstract and concrete models, it was concluded that the personalized-treatment group surpassed both the abstract-context and the concrete-context treatment groups in terms of the learning achievement and student attitudes toward the format of the lesson in teaching the division of fractions. The model design was practical in that it permitted lessons to be generated by the computer on the basis of individualized needs. However, learners were not allowed to interact with presented lesson. The parameters of this research model has prompted the question whether a similar but more specific teaching model can be extended by testing through either individualized examples or individualized examples with personalized contexts through use of an interactive, computer-assisted adaptive program.

Statement of the Problem

The National Assessment of Educational Progress (NAEP, 1979) averred that solving verbally stated problems was one of the major weaknesses in children's mathematics achievements. In 1989, the NAEP found that students continued to have difficulty in solving word problems. Several studies considering mathematics word problems concluded that the difficulty for many students seemed to stem less from the lack of computational skills than from the inability to comprehend what was asked in the problems (Cummins, Kintsch, Reusser & Weimer, 1988; De Corte, Verschaffel, & De Win, 1985; Knifong & Burton, 1985; Lewis, 1989, Lewis & Mayer, 1987; Riley, Greeno, & Hiller, 1983).

Word problems are notoriously difficult to solve (Cummins et al., 1988). In the early 1980s, Mayer (1982) affirmed that algebra story problems had earned a well-deserved reputation as a threat to students' mathematics achievements in secondary courses. In beginning algebra classes, many students had difficulty learning to solve equation word problems when confronted with abstract (e.g., the use symbolic variables such as *x* or *y*, or understanding such terms as "some" or "someone") or unrealistic (e.g., exaggerated science fiction themes) examples and contexts. Thus, a variety of strategies have been developed and introduced to overcome children's difficulty in solving word problems. From an adaptive viewpoint, a possible limitation of the strategies reviewed above would seems to be lack of sensitivity to individual differences in prior interests and experience. This implies that what comprises a meaningful presentation for one learner may not be meaningful to another.

Therefore, the purpose of the present investigation is to develop an adaptive model for an interactive CAI program and to compare the effects of adaptive CAI, based upon:

1) the use only of individualized examples which reflect the learner's interests and experience, or
2) the use of individualized examples in personalized contexts which reflect the learner's interests, experience, and biographical information.

The results of this comparative evaluation were contrasted to the traditional (i.e., abstract) presentation of word problems where no adaptation is made for individual learner characteristics. Translating word problems into equations provides the context for the CAI investigation. The research questions investigated for this study, based upon the translation of word problems into equations in an interactive CAI format, were as follows:

1) Does the use of individualized examples produce higher achievement levels than the use of abstract examples?
2) Does the use of individualized examples in personalized contexts produce higher achievement levels than the use of abstract examples?
3) Does the use of individualized examples in personalized contexts produce higher achievement levels than the use only of individualized examples?
4) Does the use of individualized examples as well as individualized examples in personalized contexts produce higher achievement levels than the use of abstract examples?

In 1984, Tennyson suggested that systematic adaptive design must originate from learning theory, and not from isolated testing of methods that may intuitively appeal to researchers. Accordingly, the theoretical framework for the present study is derived from two categorical learning approaches. First, cognitive schemata theory identifies human memory with the systematic arrangement of networks of connected facts and ideas (Anderson, 1980; Ausubel, 1968; Mayer, 1977; Rumelhart & Ortony, 1977). When new information can be easily integrated into existing schemata, meaningful learning is engendered. This interpretation suggests the advantages of individualized and personalized math examples and problems by orienting them around interesting or familiar events, people, and/or activities in the everyday lives of learners. Second, linguistic comprehension attributes math word problem difficulty to the failure of children to understand the language encountered in the problem themes (Cummins et al., 1988; Hudson, 1983; Lewis, 1989; Lewis & Mayer, 1987; Mayer, 1975). This explanation also implies that the use of individualized examples and personalized contexts serves to increase learners comprehension and the interrelations of important information in the problem statements; hence, the derivation of accurate solutions by learners is enabled.

Significance of the Study

The present study investigated both individualized examples based on learners' interests and prior experiences, and personalized contexts based on learners' interests, experiences, and biographical information. The results obtained were intended to:

a) Assist CAI designers in implementation of strategies for the improvement of the quality of instructional software;

b) Provide implications for learning theory with respect to learners' cognitive processes and learning attitudes; and

c) Provide information for the enhancement of instruction using math word problems.

Though several CAI adaptive models currently in use have been developed by computer scientists or educators, it is asserted that the algorithms provided in these models are either too impractical (e.g., confined to parallel concepts or sequential levels of difficulty) or too complicated (e.g., based upon use of the Bayesian probability model) for successful implementation. For the current investigation, the use of individualized examples and personalized contexts is not only easy to implement, it also provides flexibility and practicality when concerned with individual differences which cannot be easily accommodated in the normal classroom setting. The algorithm developed for the present study rather is reliant upon motivational effects, encouraging learners to focus attention upon the problem. This algorithm also serves to contribute to the theory of meaningful learning insofar as it enables the integration of new information into existing knowledge schemata with a certain ease. For a number of years, educators and psychologists have been concerned with learning presentations based upon the use of examples and contexts. However, their primary focus has been directed toward homogeneous subjects (i.e., concerned with entire classrooms) and has not encompased the flexibility necessary to deal with individual concerns. Thus, the primary motive underlying this study has been the augmentation of presentations based on the differing background needs of individual learners.

Definition of Terms

Abstract examples: Examples which are constructed and selected without the involvement of particular interests or specific experiences; all problems are identical for all learners.

Adaptive teaching: Teaching that arranges environmental conditions to fit differences among individual learners.

Individualized examples: Examples which are are constructed and selected based upon the interests and experiences of individual learners.

Individualized examples in personalized contexts: Examples which are constructed and selected based upon interests and experiences of individual learners, but with biographical information embedded within the example contexts.

Chapter 2

ANALYSIS OF RELEVANT LITERATURE AND RESEARCH

Introduction

This research study was concerned with the effects of individualized examples and personalized contexts in computer-based adaptive teaching. The subject matter for the investigation was the translation of word problems into equations, suggesting a review of those studies which have investigated adaptive teaching and the use of mathematical word problems from a variety of viewpoints. Thus, five areas of research, as indicated below, are reviewed in the following sections of this chapter:

1) Prior knowledge in adaptive teaching examines research findings on the desirability of adjusting learning programs with respect to learners' ability measured prior to the administration of the programs;
2) Response-sensitive instructional strategy in adaptive teaching examines research findings on attempts to adjust learning programs continuously with respect to learners' on-task responses;
3) Cognitive style, learning style, and personality in adaptive teaching examines research findings on endeavors to allow for a diversity of learners' personalities and learning characteristics;
4) Individualized and personalized contexts in adaptive teaching examines research findings on adaptive teaching by the use of individualizing and personalizing learning contexts; and

5) Research findings on the current state of the solution of mathematical word problems.

Prior Knowledge in Adaptive Teaching

Prior knowledge or prior achievement has been used as the basis for adaptive teaching for two decades. Tobias (1976) proposed a modification of Cronbach's Aptitude × Treatment Interaction (ATI, 1957) approach to the concept of achievement-treatment interactions. Since the interactions derived from this approach proved difficult to determine, the achievement-treatment interaction approach shifted the focus of adaptation from general traits and aptitudes to task-specific measures of the prior familiarity of students with the material to be learned. The basic hypothesis underlying the modified approach was that the higher the level of prior achievement, the lower the level of instructional support required to accomplish objectives; conversely, the lower the level of prior achievement, the higher the level of support required to accomplish objectives. Thus, four studies of adaptation based on learners' prior knowledge are reviewed.

Gay (1986) focused on an examination of the effects of prior conceptual understanding and learner control on performance in computer-assisted video instruction. Computer-assisted instruction (CAI) using interactive videodiscs was a new instructional technology that sought to combine the power of the microcomputer with video and audio capabilities provided by the laser videodisc. The interactive videodisc system can be used to provide random access to a variety of video, audio, and computer texts or graphic information, thus allowing a high degree of learner interaction. The Gay research hypothesis was that students who had some prior conceptual understanding would learn best when given control and that students with lower prior conceptual understanding would learn best when provided with structure (i.e., learner control versus program control).

A 23-item pretest (Cronbach alpha = .73) was administered to 156 volunteer students at Cornell University (Gay, 1986). The test measured the subject understanding of the protein synthesis process. On the basis of pretest scores, 80 subjects were selected, 40 from the low-conceptual-understanding group and 40 from the high-conceptual-understanding group, and then assigned to receive, respectively, program-controlled or learner-controlled treatments based upon the use of systematic randomization to obtain equal numbers for each treatment condition. Subjects were allotted a two hour time period in which to study four modules on DNA structure and the transcription phases of protein synthesis in one of two treatments formats. First, under the program-controlled treatment, material was sequenced logically by ordering the computer text, graphics, and video and audio segments to reflect the hierarchical nature of the topic structure. Second, under the learner-controlled treatment, subjects controlled the sequencing, presentation mode (i.e., video, audio, graphics, or text), the amount of practice, and the depth of study as well as the pace of the lessons.

At the end of the experimental treatment, a 20-item multiple-choice and short answer examination (Cronbach alpha = .79) was administered on-line (Gay, 1986). Since the instructional materials were presented via computers, the students were treated on an individual basis. The results of the data analysis indicated that the mean posttest score of subjects with low-conceptual-understanding in the learner-controlled treatment was significantly lower than the mean posttest scores of subjects in the other three groups. No significant differences were found between the mean posttest scores of subjects with high-conceptual-understanding in the program-controlled treatments and subjects with low-conceptual-understanding in the program-controlled condition. The results also indicated that for the use of their time, subjects with high-conceptual-understanding in the learning-controlled treatment were significantly more efficient than all other groups.

Gay (1986) observed that the findings of this experiment demonstrated that not all subjects were capable of making appropriate decisions. In terms of the post-test scores, subjects performed better in the program-controlled treatment than in the learner-controlled treatment. Following examination of the computer records of strategies used by the subjects during the experiment, it was with considerable interest that it was noted that the low-conceptual-understanding subjects tended to practice too little and to emphasize areas with which they already had some familiarity, at the same time avoiding unfamiliar or difficult topics. Seemingly, the low-conceptual-understanding subjects had difficulty determining how much practice they needed to learn a particular topic, at the same time tending to disregard review and remediation options, to repeat and over-learn topics that were already understood, and to skip segments that should have been emphasized. In summary, low-conceptual-understanding subjects did not use good learning strategies and made poor sequencing decisions under the learner-controlled treatment. In contrast, high-conceptual-understanding subjects were able to function equally well for both treatments. Analysis of the computer records indicated that the latter selected fewer examples, emphasized topics that they did not understand, used practice questions to discover areas of weakness, chose remediation and review segments, and were able to effectively organize their learning strategies.

Schloss et al. (1988) compared the performance of students completing higher cognitive modules when exposed to two feedback conditions: forced looping and optional looping. This study addressed three questions: 1) Would students with relatively high SAT scores demonstrate better CAI performance than students with low SAT scores; 2) were CAI modules, in which students are allowed to choose to review material following an error, superior to those in which the review was imposed; and 3) would the achievement level of students, and the choice or absence of choice in the modules, interact to produce better performances among high achievers using the choice loop module and worse performances among low achievers using the optional loop module?

Fifty-two undergraduate students enrolled in two introductory special education classes at Pennsylvania State University were the subjects for the investigation, with students whose total SAT scores were between 900 and 1000 excluded from the study (Schloss et al., 1988). Students with SAT scores above 1000 were designated as high achievement (HA, n=25) group members while those with SAT scores below 900 were designated for a low achievement (LA, n=27) group. The authors noted the SAT was a standard aptitude test commonly used to predict achievement in college. The two CAI modules prepared for the study, the forced loop (FL) and the choice loop (CL), included discussions of special education referral procedures, protective safeguards and due process, individualized education programs, multidisciplinary teams, confidentiality, and parental rights and responsibilities. One-half of the HA and LA students were randomly designated for the FL condition and one-half were designated for the CL condition.

Two 30-item objective tests (i.e., trained and untrained tests) and one student opinion survey were used to assess the subjects' achievements and opinions toward the format of the modules, the operation of equipment, provisions for feedback, and general feelings about the CAI procedure (Schloss et al., 1988). The untrained test included items based on the content of the module which were not included as actual module items, whereas the trained test included items taken directly from the module (KR20 reliability = .79; range of internal consistency reliability = .82 to .90). The testing results indicated that the HA/FL group had the highest number of correct responses, whereas the LA/CL group had the lowest scores. Significant differences were not obtained for a CL/FL contrast or for achievement by CL/FL interactions.

However, in the opinion survey, the HA/FL group expressed the strongest positive opinions toward the modules, while the HA/CL expressed the least positive opinions. Results also indicated that low achieving participants required more time to complete the FL module than they required to complete the CL module. The high-ability students required less time to complete the modules than low-ability students, regardless of the looping condition.

It should be noted that the treatment conditions and the means of data analysis (Schloss et al., 1988) were poorly designed for two reasons. First, without time for reading, subjects in the FL groups could press the return key immediately following display of the information on the screen; in contrast, subjects in the CL groups were allowd to review the information each time they provided an incorrect response since the answer could easily be found on the information screen. Second, in comparison to the Gay (1986) study, which allowed control of the more important program elements, the means to control feedback were trivial and the results were thus less meaningful than those obtained by Gay. Due to these two defects, the results of this study were inconclusive. In addition to these drawbacks, the quality of the instructional program was unknown, and the sample size was too small and uneven by gender (i.e., 49 females versus three males), thus restricting the generalizability of the findings.

Goetzfried and Hannafin (1985) tested the effect of CAI locus of control strategies on processes for learning mathematics rules, examining the effects of externally versus internally controlled CAI design strategies, retention, and efficiency among low achieving junior high students. Forty-seven seventh grade students enrolled in remedial mathematics classes participated in the study. The subjects were selected based on poor performance on a standardized test, the Comprehensive Test of Basic Skills, administrated to all subjects eight months prior to the study. For prior mathematics achievement, the twentieth percentile was the median score used to classify students as "below average" or "low" (i.e., subjects below the twentieth percentile were low achievers, while subjects above the twentieth percentile were classified as below-average achievers for purposes of the study). Subjects were randomly assigned to one of the three treatment groups; stratification assured that approximately equal numbers of males and females with low and below average achievement scores were assigned to each of the treatment groups.

The learning program was a mathematics rule lesson concerning divisibility by two, three and five (Goetzfried & Hannafin, 1985). Three versions representing different CAI design strategies were developed: adaptive control, learner control, and linear control. The adaptive control version consisted of externally-controlled CAI based on the accuracy of learner responses. The learner control with advisement consisted of internally-controlled CAI, during which process subjects were continuously advised of progress toward objectives and permitted to determine if reteaching, additional examples, or additional problems were needed. In linear control, subjects received the same sequence of instruction and examples, but in the absence of individual control of review or selection of additional examples or externally imposed program decisions based upon the accuracy of responses. A posttest and a retention test were administrated after the treatment to assess achievement. Data analysis indicated that the below-average students scored higher across both the rule and application scales, but proportionately higher on the application items. Although differences in achievement resulting from the various design strategies could not be found, analysis of the instructional time revealed significant differences in instructional time among the CAI strategies. The linear strategy required less time to complete than either the externally-controlled adaptive strategy and the learner-advisement strategy. The linear control strategy was determined to be the most efficient approach, followed in succession by the adaptive and the learner-control with advisement strategies.

Based upon these findings, it was noted that the results could be interpreted in support of advocates of learner-control strategies as an appropriate response to the self-evaluation deficiencies of low achievers (Goetzfried & Hannafin, 1985). Younger and less able students had less background knowledge in the content area of the instruction and consequently were less effective in arriving at judgments about personal progress and the need for additional instruction. Overall, the design of the control treatments was well prepared and the sample, limited to low achievement students, was clearly described. Finally, it was claimed in that "the methods employed and questions addressed in this study have permitted the inclusion of two important practical instructional dimensions not typically evaluated: time and efficiency" (p. 278).

Ross, Rakow, and Bush (1980) examined an adaptation strategy to teach prerequisite mathematical operations in an undergraduate statistics course. The participants were 105 undergraduate volunteers enrolled in a basic educational psychology course. The material to be learned consisted of five rules covering basic mathematical and algebra operations, including inequalities, factorials, exponents, order of operations, and summation. Subjects were randomly assigned to five treatments: 1) adapted examples and incentives; 2) adapted examples; 3) adapted incentives; 4) standardization of both conditions; and 5) subjects "mismatched" to both conditions.

A pretest was administered and the scores were then used to formulate prescriptions, as required by treatments, for the instructional phase (Ross et al., 1980). The standard level selected as optimal was six examples, with adaptation ranging from a minimum of two examples to a maximum of 10 examples, based upon individual needs. Incentives were maintained at the constant level of 30 points per rule in the standard incentives treatments. For the adaptive treatments, rules were rank-ordered for individuals based on their associated pretest scores, ranging from 10 to

50 points. A posttest was administered to assess the learning outcomes (KR20 reliability for pretest and posttest were, respectively, .83 and .82). Data analysis indicated that adapting the number of examples yielded significant performance results on the posttest, but that the comparisons between incentive variations were inconclusive. The results indicated that there was an achievement-treatment interaction: The higher the prior achievement score by the learner, the lower the level of instructional support required; conversely, the lower the prior achievement level score by the learner, the higher the level of instructional support required. It should also be noted that for this study, a self-management learning system which could not be generalized to normal classroom instruction was examined, and that prescription was assigned by the experimenters and not by computer.

Thus, four studies concerning the prior knowledge in adaptive teaching have yielded some meaningful results. First, prior knowledge can provide a useful basis for identifying individual needs and adapting instructional prescriptions. Second, exposed to learner-control treatment, low-prior-knowledge students do not use good learning strategies. When time and efficiency are considered, students in this category learn better under adaptive program-control treatment conditions, or even under linear program-control treatment conditions. Third, high prior knowledge students learn equally well in both learner-control and program-control conditions. However, they are able to complete their learning programs more quickly under the learner-control condition.

Response-Sensitive Instructional Strategy in Adaptive Teaching

In spite of consistent efforts by cognitivists and neurophysioloists, reliable techniques for the observation and analysis of human cognitive information processing have not been developed, nor is it likely that such tools will be developed in the forseeable future (Park, 1983). As Cziko (1989) observed,

> considering the complexity of the constantly changing interacting factors influencing human behavior, Cronbach and Snow conclude that comprehensive and definitive experiments in the social sciences are not possible and that the most we can ever realistically hope to achieve in educational research is not prediction and control but rather only temporary understanding. (p. 17)

Since human behaviors are to some degree unpredictable, the best means to monitor or estimate an individual student's cognitive learning processes on a given task is to continuously analyze the student's learning performance. The student's updated performance level and learning needs can be reflected in on-task responses demonstrated during instruction. According to research conducted by Park (1981, 1982) and by Tennyson and Rothen (1977), the student responses to a given task are activated to achieve expected learning outcomes for that specific task. An instructional procedure which continuously analyzes individual student performance or response during instruction, and then sensitively reacts to the response, is called a response-sensitive instructional strategy (RSIS) or the Minnesota Adaptive Instruction Strategy (MAIS). The developers of the RSIS, Tennyson and Rothen, had high expectations for the potential uses of their instructional strategy and have conducted a number of studies to test its implementations. The effects of this instructional approach strategy is reviewed in this section.

Tennyson and Rothen (1977) investigated the effect of the pre-task and on-task adaptive design strategies for selecting the number of instances in concept acquisition, testing the premise that the number of instances necessary in a concept learning task could be determined by individual differences and needs. Their first hypothesis was that an adaptive design strategy that used premeasure (aptitude), pretest (prior achievement), and on-task performance (learning) data would result in more effective concept learning than an adaptive model that used only pretask (premeasure and pretest) data. Their second hypothesis was that both full (pretask and on-task measures) and partial (pretask only) adaptive design strategies would be more effective than a nonadaptive strategy.

In tests conducted among undergraduate male and female students from the general psychology subject pool at the University of Minnesota, subject (n=67) participated in three experimental conditions: full adaptive, partial adaptive, and nonadaptive (Tennyson & Rothen, 1977). Subjects were randomly assigned to treatment conditions and administered the treatment individually via computer terminals. The learning program included two legal concepts associated with court decision making: the best-evidence rule, and hearsay evidence. Subjects were required to assume the role of the judge in a civil case in a federal district court and rule on objections to questions asked of the witnesses by lawyers for either the plaintiff or the defendant.

A 20-item pretest was administered and the resultant scores were used to prescribe learning programs, as required by the treatments (Tennyson & Rothen, 1977). A posttest was administered immediately after instructional treatments to assess achievement. The learning program and the test instruments were validated by a formative evaluation, but the values of validity and reliability were not provided in the study. Following data analysis, it was concluded that subjects in the full-adaptive groups (i.e., pre-task and on-task adaptive groups) not only finished the learning task in less time than subjects administered the nonadaptive treatment, they answered 85 percent of the questions on the posttest correctly, compared to a score of 64 percent for the students in the nonadaptive group. The effectiveness ratio calculated for performance and learning time clearly indicated that on-task measures for modifying instructional length, while maintaining a specific level of mastery, could achieve significant gains in student learning over that of only pretask measures. These results suggest that the learning programs with some degree of adaptation are to be preferred to those without adaptations. Those programs using more pretask and on-task information for adaptation to learning situations provided better results than those based upon only pretask information.

For this study, a complicated formula for adapting the number of instances (i.e., the Bayesian Probability Model) and the formulae for confidence ratings were implemented (Tennyson & Rothen, 1977). This type of implementation may be easily conducted by computer and is viewed as a means to exercise rigid control of experimental situations. Controlling of the number of instances was regarded as only the initial phase in the development of the RSIS, and was thus regarded as a superficial adjustment. It was stated that in addition to the number of instances, context aspects or even learning time could be used to adjust the learning program so that a more efficient learning programs could be developed. For this study, only one variable was adjusted in the learning program, the number of examples. The effect of other critical variables in fostering learning (e.g., content sequence, forms of examples, or display time) and the multi-dimensional interactive effects remained an unknown. The short experimental time (i.e., less than 25 minutes) may have reduced the validity of the findings.

In 1980, Park and Tennyson continuously tested adaptive design strategies for selecting the number and presentation order of examples in coordinate concepts. The primary purpose of the study was to test the effect of pretask measures against on-task measures for predicting students' learning needs for a specific learning criterion. A secondary purpose was to contrast a response-sensitive procedure for the presentation of examples with a response-insensitive procedure. The participants (n=132) were tenth- and eleventh-grade male and female volunteers enrolled in social studies classes at a Minnesota high school. The subjects were assigned one treatment condition from a random list of six conditions, subject to two independent variables: information (i.e., pretask, on-task, and pretask plus on-task information) and presentation order (i.e., response-sensitive and response-insensitive). The coordinate concepts included positive reinforcement, negative reinforcement, positive punishment, and negative punishment.

A 24-item pretest was administered to pretask and pretask/on-task groups to prescribe learning programs (Park & Tennyson, 1980). All subjects received a computer-based posttest immediately following treatments. From the results of the study, it was concluded that: a) on-task information, compared to pre-task information, seemingly provided the best data for adjusting instruction to individual needs; b) the use of the pretest as a part of the instructional program did not increase efficiency, and in fact might have increased total instructional time, thus contributing to student dissatisfaction with the learning task; c) the instructional principle (i.e., increasing the number of examples would increase performance) was questionable since the number of examples was based primarily on an individual need, and simply increasing the number of examples without considering individual needs could have influenced an actual performance decrease; and d) a response-sensitive strategy in reference to an error pattern would improve performance, decrease learning time, and reduce the amount of instruction necessary.

Park and Tennyson (1980) used the Bayesian Probability Model as the basic format for adaptation to learners' needs. The effect on performance and learning time using this design strategy was supported by the positive findings of the study. However, this design can be implemented only when the learning program has several parallel items which are similar in difficulty and content length. If the learning program does not include several items, or if the difficulty or the lengths of the content items are not equally distributed, it was concluded that the design would fail to work, especially when the items in the learning program were strongly ordered by sequence and difficulty.

Tennyson and Park (1984) continued the testing of the adaptive design strategy by using process learning time as a variable in concept learning by computer-based instruction. The purpose of this study was to investigate the effect of manipulating the instructional display time for interrogatory examples to facilitate the transition, in concept learning, from prototype formation to classification skill development. Drawn from introductory biology, the coordinate concepts selected for this study were commensalism, symbiosis, and parasitism. The participants (n=96) were randomly selected from a subject pool (ninth-grade students enrolled in general science classes in Minnesota) for assignment to a specific learning appointment. At the experimental session, students were randomly assigned to treatment conditions, including process learning time (PLT), inverse process learning time (IPLT), mean process learning time (MPLT), and noncontrolled process learning time (NPLT).

An immediate computer-based posttest and two-week delayed parallel retention test were administrated to assess the subjects' learning achievement (Tennyson & Park, 1984). The learning program and the test instruments were validated by four experts and the reliability was also determined, but was not reported in the study. The results of data analysis showed that the PLT group needed significantly fewer instructional examples than the other groups, and achieved a higher posttest performance than the IPLT group. Analysis of the retention test scores also indicated that the PLT group subjects, who maintained their posttest level of performance, were significantly better on the retention test than the subjects from the other groups. In addition, subjects in the MPLT and NPLT groups performed better than IPLT group subjects.

It was determined that the instructional adjustment of display time per individual learner directly influenced concept learning in terms of time required, number of interrogatory examples needed, and level of classification performance achieved (Tennyson & Park, 1984). It was also noted that the effect was not just a matter of manipulating display time, but manipulating it in direct reference to a theory of information processing. In addition to these findings, it was noted that for the PLT condition, decreasing display time for incorrect classifications and increasing display time for correct classifications facilitated concept learning since the learner was exposed to a greater number of examples and thus had additional time to classify examples when correct solutions were provided. Both situations directly influenced prototype formation and classification skill development. However, it was noted that the classification of parallel concepts was only a small portion of the learning task in science and mathematics, occurring only when parallel concepts existed.

In 1985, in addition to testing the adaptive control of learning time, Tennyson, Park, and Christensen also tested content sequence in concept learning, using computer-based instruction. The purpose of the study was to investigate the instructional variables that would improve conceptual knowledge formation, based upon the adaptive control of the rate of learning speed by the effective reduction of selective interference and procedural knowledge development, and by adaptively controlling the sequence of examples. The participants (n=72) were male and female eleventh grade students in Minnesota, each randomly assigned to one of six instructional treatment conditions. The concepts selected for this study, drawn from the field of psychology, included positive reinforcement, negative reinforcement, positive punishment, and negative punishment. Six treatment conditions were identified, including adaptive control with generalization, adaptive control with discrimination, adaptive control with generalization/discrimination, learner control with generalization, learner control with discrimination, and learner control with generalization/discrimination groups.

A 24-item posttest and a four-week delayed retention test were used to measure achievement in knowledge of the psychology concepts (Tennyson, Park, & Christensen, 1985). Posttest scores indicated that the adaptive-controlled treatment was more favorable than learner-controlled treatment, and that generalization/discrimination treatment was significantly higher than both the generalization and discrimination treatments. On the retention tests, there was no decline in performance for the adaptive-controlled treatment, whereas there was a decline in scores for the learner-controlled treatment. Both the posttest and the retention test were validated and checked for reliability; however, the criterion for validity and the value of reliability were not noted in the study. The results of this study showed that the adaptive-controlled condition needed fewer interrogatory examples and required less instructional time than the learner-controlled condition. In addition, the combined sequence of generalization/discrimination treatment resulted in more efficient learning times than either the generalization or the discrimination treatment.

Tennyson and Buttery (1980) tested advisement and management strategies as design variables for CAI, based upon the hypothesis that a learner-control strategy with advisement would not only be as effective in student acquisition of the learning task as an adaptive control strategy, but also that it would be more efficient in terms of student on-task learning time. The coordinate concepts selected were positive reinforcement, negative reinforcement, positive punishment, and negative punishment, tested for a computer-based instructional treatment program with four conditions: Group 1, learner control with advisement; Group 2, adaptive control with advisement; Group 3, learner control without advisement; and Group 4, adaptive control without advisement. The subjects ($n=139$) were twelfth grade male and female students from psychology classes in Minnesota, each randomly assigned to one of the four treatment conditions.

After analysis of the pretest and posttest data, it was concluded that the conditions using the adaptive information (i.e., adaptive control and learner-adaptive control) had identical posttest-score means, but that the learner control with advisement condition showed significant decreases in on-task time and amount of instruction, respectively, 22 and 25 percent (Tennyson & Buttery, 1980). That is, a learner-control condition could be a valuable instructional management system, especially for computer-based instruction, if students received sufficient information about their learning development and were continuously shown progress made toward mastery of the objective. The learner-control condition provided meaningful advice on the appropriate stimuli necessary to obtain this goal.

Tennyson (1980) tested the effects of instructional control strategies and content structure in concept acquisition, using computer-based instruction, hypothesizing that the learner-adaptive control strategy (i.e., the condition using advisement) would not only be as effective as the adaptive strategy in acquisition of the learning task, but would also be more efficient in terms of student on-task learning times. Whether the simultaneous presentation of rules would also result in improved performance with respecto to the successive or random presentation of rules was also tested. The participants (n=135) were undergraduate students from the University of Madrid enrolled in introductory physics classes, assigned to treatment conditions as they appeared for the experiment. The coordinate concepts selected for this study, drawn from the field of physics, were force, power, velocity, and speed.

In the learner control strategy, the students decided (a) whether to continue receiving instances or to proceed to the posttest and (b), for the simultaneous condition, which concept they wanted to see next (Tennyson, 1980). The learner-adaptive control used a learner-control-management strategy that (a) allowed students to decide whether or not to continue receiving instruction and (b) advised them on the number of instances needed to reach mastery for each concept (i.e., with diagnosis and prescription information as determined by the MAIS model). For the simultaneous condition, students were also advised which concept example to select next. Program directions (a) informed students about the learner control format and (b) told them that the advisement information was determined according to their individual learning development in relation to concept mastery, which would aid them in deciding the amount and the sequence of instruction. For the simultaneous condition, one example from each concept was arranged so that the variable attributes were similar within a set, but were different between sets. Once concept mastery was obtained, examples from that concept were dropped from succeeding rational sets, except when needed for discrimination learning. In contrast, the successive condition presented concepts one at a time. Once mastery was obtained for a given concept, the next concept followed and the process was repeated until all four concepts had been presented.

A 30-item syllogism test and a 24-item pretest were administered and scores were then used to prescribe the learning program (Tennyson, 1980). A multiple-choice styled posttest was administered to assess achievement in physics concepts. The results of the data analysis indicated that subjects receiving the simultaneous presentation of coordinate or parallel concepts needed significantly fewer instructional examples than students who received more examples in the successive condition. The advisement variable was highly significant in providing subjects, in the learner-adaptive control condition, with meaningful information with which to make appropriate decisions about the acquisition of the coordinate concepts. The two conditions using adaptive information (i.e., adaptive control and the learner-adaptive condition) reflected identical posttest score means, but the learner-adaptive control condition showed a significant decrease (24%) in on-task time. Again, these findings supported learner control instructional strategies.

In 1981, Tennyson tested the use of adaptive information for advisement in conceptual rule learning, using CAI. Two experiments were conducted for this research. First, the advisement variable was contrasted directly with a conventional learner-control management strategy and a program managed adaptive-control strategy. Second, the learner-control strategy with and without advisement was tested over several separate units of instruction. The participants (n=63) in the first experiment were twelfth-grade female and male students enrolled in physics classes at a suburban high school in Minneapolis, Minnesota. From a random list of three CAI treatment conditions, subjects were assigned to one of the treatment conditions as they appeared for the experiment. Participants (n=47) for the second experiment were eleventh-grade male and female students enrolled in English classes at the same school, each assigned to single condition from a random list of three treatment conditions.

In the first experiment, the learner-control treatment condition, the subjects decided (a) whether to continue receiving examples or to go to the posttest and (b) which concept they wanted to study next (Tennyson, 1981). For the adaptive-control treatment condition, the MAIS management system continuously selected the number of examples presented to each subject, based upon the subject's pretest and on-task performance in relation to the learning objective, following which the concepts were sequenced according to the subject's response pattern to each given example. In the learner-adaptive-control treatment condition, a management strategy was used that (a) allowed students to decide whether or not to continue receiving instruction and (b) advised them on the number of examples needed to reach mastery for each concept. In the second experiment, program directions for the learner-adaptive-control condition informed subjects that: 1) An initial section of the instruction would, in addition to presenting examples of the rules to be learned, assess their learning progress; (2) following the initial section of program control, they would be advised of that assessment for the purpose of helping them select examples in the second (learner-control) section; and (3) assessment and advisement would be continuous until they decided when to end the instruction and take the posttest.

For both experiments, posttests were used to assess the effects of treatments (Tennyson, 1981). In the first experiment, the mean correct score for the learner-adaptive control condition was equivalent to the adaptive-control condition, both of which were higher than the learner-control condition. Data analysis also indicated that the subjects in the adaptive-control condition took greater lengths of time than the subjects in either the learner-adaptive-control condition or the learner-control condition. In the second experiment, the learner-adaptive-control condition posttest score was higher than either the learner-partial-control condition or the learner-control condition. Thus, the intent of the study was to solve the problems occurring in both learner-control and program-control CAI programs. Boredom could have been a major factor in performance deterioration in the former; however, for the latter condition, the learner often terminated instruction too early and failed to learn the defined objectives. The findings of this study indicated that the combination of learner-control and diagnostic and prescriptive information generated satisfactory improvement. Seemingly, advisement was a useful variable for the design of adaptive CAI; however, meaningful advisement was not be easily achieved. The use of a complicated statistical formula and a mathematical model did not serve to assure its validity or accessibility, particularly when computers were not available.

Each of the studies considered in this section were conducted by Tennyson and/or Park, or one of the two in conjunction with their associates. The designs were based on the Bayesian Probability Model and the MAIS was the principal test instrument. These studies provided several meaningful findings. First, students in the adaptive groups seemingly experienced greater learning enhancement than subject placed in the nonadaptive groups. Moreover, an adaptive design strategy that used both pretask and on-task performance data resulted in more effective concept learning than an adaptive strategy that used only pretask data. Second, the instructional adjustment of display time per individual learner influenced concept learning in terms of time required, the number of interrogatory examples needed, and the level of classification performance achieved. In other words, decreased display time for incorrect classifications and increased display time for correct classifications facilitated some level of concept learning. Third, adapting the sequence first to conceptual knowledge formation and then to procedural knowledge development improved efficiency in conceptual learning. Fourth, a learner-control strategy with advisement was not only as effective in student acquisition of the learning task as the adaptive control strategy, but was also more efficient in terms of student on-task learning time. The advisement process implied a quantity of meaningful information. At the start of the instruction, students were advised of their initial level of knowledge in comparison to the desired learning criterion (diagnosis) and the amount and sequence of instruction necessary for them to obtain the objective (prescription). During the learning program, students were continuously advised of the task of their learning development (updated diagnosis) and the instructional needs (updated prescription) necessary for task mastery. Thus, the subjects were provided, respectively, with a diagnosis, a prescription, an updated diagnosis, and an undated prescription. Finally, students receiving the simultaneous presentation of coordinate concepts needed significantly fewer instructional examples than students who received more examples in a successive condition.

The generalizability of these studies was limited due to the short experimental times used. For these studies, the algorithm was implemented only when the learning concepts had several parallel items similar in difficulty level and content length. Program designs were limited to clearly categorized learning tasks that did not require operational skills. Rational sets of examples were not easily determined when learning concepts were not clearly categorized. On the other hand, these studies did not address the fact that learning programs with heavy operational skills require learning not only concepts discrimination, but also the operating procedures, in addition to which the learning tasks concentrated on the knowledge level, the lowest level of learning. Other important higher level tasks, including comprehension, application, analysis, synthesis, and evaluation (Bloom, 1956), were not investigated.

Cognitive and Learning Styles and Personality in Adaptive Teaching

Learners' cognitive and learning styles in the context of individual personality have been viewed as characteristics which are most difficult to evaluate and control among learners. Most of the studies involving these characteristics have not been well designed or have proved to be inconclusive.

Roberts and Park (1984) tested the effects of feedback on a CAI program with different cognitive styles, namely, field dependent (FD) and field independent (FI), based upon the theory that FI individuals were better able to perceive visual stimuli in complex fields than FD individuals. The study was designed to assess three hypotheses: 1) Subjects who received explanatory feedback would perform better than subjects who received only knowledge of the correctness of their response; 2) FI subjects would perform better than FD subjects; and 3) FI subjects would perform the same regardless of the type of feedback they received, while FD subjects would perform better with explanatory feedback than when provided only with knowledge of results feedback. Eighty male and female undergraduate students from the University of Minnesota voluntarily participated in the study. The set of concepts considered, drawn from the field of psychology, were positive reinforcement, negative reinforcement, positive punishment, and negative punishment.

The first independent variable, feedback strategy, had two levels: knowledge of response result only (KRO) and explanatory feedback (KRE) (Roberts & Park, 1984). Subjects were classified FI or FD, based upon the Group Embedded Figures Test (GEFT) (Witkin, Otlman, Raskin & Krap, 1971). The four treatment conditions were thus: Group 1, field independent and knowledge of response results only (FI/KRO); Group 2, field dependent and knowledge of response results only (FD/KRO); Group 3, field independent and explanatory feedback (FI/KRE); and Group 4, field dependent and explanatory feedback (FD/KRE). A computer-based, multiple-choice posttest was administered to assess subject learning outcomes. The results of data analysis indicated that the KRO subjects required more examples than subjects who received explanatory feedback to achieve the mastery criterion. Likewise, the FD students required more examples than the FI students to reach the mastery criterion, and the FD/KRO group needed more examples than the other three groups. In addition, the results showed that the FI/KRE group scored significantly higher than either the FD/KRO group or the FI/KRO group.

The most consistent and strongest results suggested by this study was connected with instructional feedback (Roberts & Park, 1984). Feedback contained both knowledge of correctness and explanatory information, resulting in better achievement than the feedback that provided only knowledge of correctness. This effect was shown for FD and FI subjects alike. Thus, the effect of explanatory feedback was supported. However, these results indicated only that explanation is beneficial in feedback, not how such feedback might be optimally constructed. Previously, Brown and Burton (1978) had determined that a majority of student errors in the solution of arithmetic problems were not random errors, but rather the systematic application of incorrect procedures. Thus, Roberts and Park had designed explanatory feedback to mirror the general instructional approach taken by explaining how the correct answer could have been deduced. Brown and Burton had suggested that explanatory feedback included not only the statement of a correct answer, and why that answer was correct, but also focused on the subject errors, identifying response-specific feedback in the attempt to explain why given responses were incorrect.

Sales and Williams (1988) tested the effect of adaptive control of feedback in computer-based instruction, investigating the effects of adaptive feedback presentation strategies in concept acquisition and possible interactions among learning styles and types of feedback. These following premises formed the basis for the study: 1) Elaborative feedback contains additional instructional information for use by the learner; 2) Individuals with different learning styles differ in the amount of instructional support (e.g., elaboration of feedback) they need or prefer; and 3) Computer-based instruction provides a means for individualizing instruction by accommodating specific learner characteristics. Ninety college juniors enrolled in the elementary teacher license program at the University of Minnesota volunteered as subjects.

Cumulative grade point averages (CGPA), were used as indication of scholastic aptitude (Sales & Williams, 1988). The Learning Style Inventory, a 12-item self-report device designed to measure the learning preferences of individuals, yielded alternative types of data scales: 1) internally-scaled Cartesian coordinates for Abstract Conceptualization (AC) minus Concrete Experience (CE) and Active Experimentation (AE) minus Reflective Observation (RO); and 2) anominally-scaled variables for learning style types (i.e., Accommodator, Diverger, Assimilator, Converger), indicating the quadrants in which the subjects were located (Kolb, 1985). The coordinate concepts presented were five levels of intellectual skills, including discriminations, concrete concepts, defined concepts, rules, and problem solving, as presented in Gagne's (1977) "Taxonomy of Human Capabilities." The lesson contained four major components: a) definitions and best examples, b) expository instances and attribute isolation, c) interrogatory (practice) items, and d) feedback. The three treatment conditions included late-adaptive control (LAC), early-adaptive control (EAC), and program control (PC). An immediate posttest and a one-week delayed retention test were administered to assess learning outcomes.

Data analysis produced no significant treatment differences according to learning style (Sales & Williams, 1988). On closer examination of the data, subjects from the AC groups (i.e., Convergers and Assimilators) chose significantly more options than did subjects from the CE groups (i.e., Accomodators and Divergers). Data on feedback selection patterns suggested that feedback preferences were the same within and between learning styles. In the adaptive-control treatment, the

Accommodators' performance improved as they progressed through the practice portion of the lesson; that is, the number of Accommodators who regained control of feedback grew as the practice was continued. In contrast, Divergers were inconsistent in performance. One strength in the Accommodator learning style was the ability to quickly adapt to new situations; in this situation, Divergers could have become discouraged upon losing control of the feedback selection.

Carrier et al. (1985) conducted a research study to examine the effects of general ability and locus of control (LOC) on the selection of instructional options in a computer-based concept lesson. As defined, LOC related to individual perceptions of whether personal successes and failures were the result of their own actions or the result of other factors or persons. Individuals who attributed success and failure primarily to their own actions were said to have a high internal LOC; those who attributed success and failure primarily to other persons or factors were said to have a high external LOC. Participants in this study included 65 sixth-graders enrolled in four computer literacy classes at a private school near Minneapolis, Minnesota. The computer-based lesson taught about four propaganda techniques used in advertisements. General ability was assessed by use of the composite score on the Otis-Lennon Mental Ability Test (1967) and Crandall's (1965) Internal Achievement Rating Survey (IARS) was used to measure subject LOC. The reliability of the test was .96.

Three computer-based lesson versions were developed as treatments: options, full, and lean (Carrier et al., 1985). For the options treatment, students were allowed to choose various instructional elaborations as they progressed through a lesson. In the full option, subjects review all of the instructional material for the entire lesson. In the lean option, subjects were exposed only to the core lesson. Immediate and delayed posttests were used to measure the effects of both learner characteristics (i.e., general ability and LOC) and the treatments.

Carrier et al. (1985) had predicted that subjects with an internal orientation would believe that their own efforts on academic tasks would lead to successful achievement, they would thus be likely to take advantage of opportunities for further information and practice. In turn, subjects with an external LOC would characteristically believe that how well they performed would be determined by other than their own efforts. However, the results did not support these hypotheses. Rather, data analysis indicated that students with high general ability tended to want to see more optional materials than students of lower ability. A weak finding which supported the research hypothesis was that in delayed posttest, the subjects who scored high on the IARS achieved more under the full treatment than under either the option or lean treatments. Children with high internal scores typically demonstrated great persistence in the pursuit of academic tasks. However, even with this finding, the effects of learning style and the interactions between learning style and control strategies were not only unclear, but proved to be inconclusive. It was concluded that "the relationships between learner characteristics and control within instruction appears to be complex" (p. 211).

Lopez and Harper (1989) attempted to test the relationship between learner control of CAI and LOC among Hispanic students. The purpose of the study was to investigate the effects of three levels of learner control (i.e., no learner control, moderate control, and high control) on the achievement and motivation of Hispanic students when studying a microcomputer-delivered lesson. The performances of internal and external LOC subjects were compared across the three levels of learner control. The subject were 101 Hispanic seventh and eighth grade students from six classes in an urban school with a primarily Hispanic enrollment, each studying a lesson upon insects. The Intellectual Achievement Responsibility (IAR) scale (Crandall, Katkovsky, & Crandall, 1965; test-retest reliability coefficient = .65) was administered two weeks before the experimental treatments. Subjects were classified as internal or external on the basis of a median split in the total IAR score. A 25-item posttest and a questionnaire were administered to assess the outcome of learning and learners' attitude toward CAI versus paper-pencil instruction. Posttest inter-item reliability, calculated with KR20, was .72.

Neither the difference for type of control, nor for sex, was statistically significant (Lopez & Harper, 1989). Mean overall achievement scores for LOC were nonsignificantly different. Chi-square analysis revealed a preference for computer-based instruction. However, it was determined that the halo effect may have existed in this study. In addition, the study did not support the notion that individuals with an internal LOC perform better when they are able to control their environment. Although the research raised questions about the usefulness of the concept of LOC as related to instruction, it was only a single study conducted with a specialized group of subjects (Hispanic students). Before determining whether LOC has implications for instruction and instructional design, further research among more general subject groups will be required.

Review of the material considered in this section suggests that cognitive and learning styles, and personalities of learners are characteristics which have proven to be difficult to control and evaluate. Most of the studies considered were not well designed and their results were generally questionable. Seemingly, these characteristics have only a weak correlation with factors of student achievement. Furthermore, interaction between these characteristics may be ambiguous, a factor which may make research in this area even more difficult.

However, some noteworthy observations may be derived from these studies. First, for CAI programs, instructional feedback which contains both information on the correctness of results as well as explanatory information results in better achievement than when only the correctness of the results are provided. This effect was demonstrated both for different cognitive styles and for different learning styles.

Second, a weak correlation was found between performance and student learning styles or personalities in CAI learning programs.

Individualized and Personalized Contexts in Adaptive Teaching

An intractable problem exists, when giving examples and practice problems where frequent emphasis is made to abstract and technical themes, in conventional math and science textbooks. To solve those problems, first must translate unfamiliar vocabulary and determined the meaning of problem situations that have little relation to their real-life experience. This problem has been viewed as the principal reason for poor student performances on story problems. A number of researchers have attempted to deal with this problem by the use of computers to deliver learning materials that offer an adaptive learning context for each learner.

Ross (1983) conducted two experiments to examine the effect of increasing the meaningfulness of quantitative material by adapting the context to student background. In the first experiment, preservice teachers studied statistical probability rules presented in three different contexts, namely, education-related explanations and examples, medical-related contexts, and abstract contexts. The second experimental design was identical for nursing students as subjects. For the first experiment, subjects were 51 preservice teachers enrolled in junior-level educational psychology courses. Each was randomly assigned to three context treatments: abstract, adaptive-E (education), and nonadaptive-M (medical). The learning material consisted of a lesson on probability covering the following four introductory rules: probability statements, addition involving mutually exclusive events, addition involving nonmutually exclusive events, and multiplying probabilities for independent events.

The abstract context version was developed first, using abstract terms and symbols as referents in all explanations and problems (Ross, 1983). The education context was then prepared by substituting meaningful, educationally oriented referents (e.g., students, teachers, and homework) for the abstractions, providing the problem with an applied focus (e.g., guessing factors on exams). The medical context was then constructed in the same way, except that the situations involved doctors, nurses, and patients concerned, for example, with the probability of recovery rates, accuracy of diagnosis, or the incidence of illness. The subjects were first administered a 10-item pretest on basic math and algebra. Achievement measures consisted of immediate and delayed posttests on the probability rules. An 8-item semantic differential question test asked subjects to rate their reactions to the learning task by choosing one of eight spaces positioned between positive and negative adjectives.

In the data analysis, both immediate and delayed posttests associated education-related contexts with an advantage relative to the two other contexts for conventional problems conveying education themes and an advantage relative to the abstract context for transfer problems (Ross, 1983). Therefore, the important factor would appear to have been the relevance of the contexts employed to shared interests of the subjects in education and teaching.

In the second experiment, subjects were 50 nursing students enrolled in the same introductory statistics course that formed the basis for materials and procedures used in the first experiment (Ross, 1983). Individual assignments to the three context treatments was made at random, resulting in final treatment numbers of 16 for the adaptive-M context group and 17 each for the nonadaptive-E and abstract context groups. The results indicated the superiority of adaptive-M with respect to each of the other treatments. That is, nursing students achieved higher performances on medical-oriented items than on educational-oriented items. Based upon the findings, it was concluded that the importance of this study resided in the manipulation of context familiarity in terms of the relationship of themes to student backgrounds. Preservice teachers benefitted from education-related materials, but not from medical-related materials, whereas nursing students demonstrated the opposite tendency.

Ross, McCormick, and Krisak (1986) extended the Ross (1983) investigation by examining the effects of individualized, relative to group-based context selections. The research hypothesis was that individualized context selection would be more beneficial to performance than group-based selection. Materials were adapted from Ross (1983) and employed for nursing majors in the first experiment and education majors in the second experiment. For the material selection variable, learner choice allowed individuals to select a preferred context as the focus of lesson examples and explanations. The options presented were medicine, education, sport, and abstract.

In the first experiment, subjects were randomly assigned to four treatment groups: 1) standard-adaptive, in which all subjects were administered the medical context as the standard lesson; 2) standard-nonadaptive, in which all subjects were administered an abstract context as the standard lesson; 3) learner-control adaptive, in which subjects expressed context preferences by rank-ordering the four context options from most to least favored; and 4) learner-choice nonadaptive, in which subjects ranked-ordered the four context options as just described, but were administered the thematic context that they ranked lowest (i.e., medicine, education, or sports, but not the abstract) (Ross et al., 1986). Achievement was measured by a 20-item posttest and a recall test, which assessed the extent of recall specific context information. An attitude questionnaire surveyed subject attitudes toward the lesson. The result of analysis indicated that the medical context was a clearly preferred theme for the two learner-choice groups. On posttesting, the adaptive groups were found to be superior to the nonadaptive groups, and the attitude survey results favored adaptive contexts over standard contexts. The second experiment was identical to the first, with the exception that the subjects were undergraduate education majors. The results of the second experiment indicated that sport and education contexts were the most popular contexts, and higher overall achievement was demonstrated by the adaptive groups relative to nonadaptive groups.

Anand and Ross (1987) tested the effect of using CAI to personalize arithmetic materials for elementary school children. Their goal was to develop and evaluate a potentially more powerful and practical adaptive strategy. Based upon the general assumption that embedding math rules in highly familiar and meaningful contexts would improve learning, two hypotheses were identified. First, personalized contexts would increase task motivation by describing applications of high interest to learners. Second, personalized contexts would increase comprehension by helping learners interpret and interrelate important information in the problem statements. The subjects were 96 fifth- and sixth-grade children from a university-affiliated elementary school. Three parallel versions of a CAI unit on the division of fractions constituted the abstract, concrete, and personalized contexts.

The achievement posttest consisted of 11 items used to measure different learning outcomes (Anand & Ross, 1987). An eight-item attitude questionnaire was devised for the assessment of student reactions to various instructional aspects, and items consisted of statements to which respondents indicated levels of agreement or disagreement on a 5-point Likert scale, ranging from strongly disagree (1) to strongly agree (5). The internal consistency reliabilities, computed with KR20, were .79 and .75 for, respectively, the posttest and the questionnaire. The results of data analysis indicated that the order of context treatments for most of the dependent measures was 1) personalized, 2) concrete, and 3) abstract. The last item of the attitude survey asked students to describe their feelings about math problems of the type given. Of the 21 positive responses from the personalized group, 10 explicitly referred to the helpfulness of personalized problems.

The findings determined by Anand and Ross (1987) were consistent with those from previous studies in which meaningful contexts were used to facilitate mathematics learning (Mayer, 1977, 1978; Ross, 1983; Ross et al., 1986). The results implied that adapting problem contexts to student interests could be an effective means to reduce comprehension problems, and to simultaneously improving attitudes toward learning math materials. With modern accessibility to microcomputers, it was stated that such a strategy would also be practical. However, the CAI program was not well designed. The subjects read only materials provided by the computer program, and the only difference between textbook learning and the CAI program was that the computers provided individual copies with different learning contexts while the textbook did not.

Ross and Anand (1987) extended their previous research on personalized math instruction in a study which varied the contexts of math word problems to increase individual meaningfulness. It was hypothesized that personalized contexts would improve performance on achievement measures by increasing motivation and facilitating assimilation of the information taught with existing knowledge. Subjects were 54 fifth- and sixth-grade students attending a university-affiliated elementary school, each of whom was randomly assigned to abstract, concrete, and personalized context groups to study a unit on the division of fractions. The materials used were adapted from Anand and Ross (1987), including a biographical questionnaire with a two-item pretest, three versions of the CAI program, a posttest, and an attitude questionnaire.

The results indicated that the personalized-context group performed significantly better than eith the abstract-context or concrete-context groups (Ross & Anand, 1987). For the solution of context and transfer problems, it was claimed that the personalized-context group was superior to both the abstract- and concrete-context groups. However, the CAI program was limited to reprinted individual materials, not allowing the learner any degree of involvement in any other activity except reading. Thus, the interactive capabilities of computers were not utilized.

Lopez and Sullivan (1991) investigated the effect of personalization of instruction on the achievements of rural Hispanic children for one-step and two-step mathematical word problems. The subjects were 68 eighth-grade Mexican-American students. Two parallel versions of instruction on the division of whole numbers were developed: a standard version, and a personalized version. The standard version used standard referents from math textbooks, whereas the personalized version was developed with referents inserted as appropriate in the original standard context. In addition, for the personalized version referents were inserted by computer for each individual, including the student's name, date of birth, and favorite items. Subjects were blocked by sex, then randomly assigned within blocks to either a standard or personalized version.

A 16-item posttest covered instructional objectives which were identical to those given for the practice and review problems (Lopez & Sullivan, 1991). Posttest inter-item reliability, calculated with KR21, was .77. Data analysis revealed that subject to personalization, females scored only moderately higher than female subjects exposed to the standard version, whereas males scored much higher for personalization than for the standard condition. In addition, the finding yielded a significant overall effect for personalization on achievement. The authors concluded that personalization may not only build stronger associations related to the task, but in doing so, it may also ease the cognitive demands imposed by the problem-solving process. The results were consistent with the findings of other personalized context studies (Anand & Ross, 1987; Ross et al., 1986).

Davis-Dorsey, Ross, and Morrison (1991) conducted a study to examine applications to mathematics problem solving as specifically conveyed through the conditions of context personalization which tapped individual schemata and problem rewording, thus making problem element interrelations more explicit. It was hypothesized that higher-ability subjects would show the highest capabilities in translating standard textbook problem forms, and would thus be less influenced by any motivational or cognitive benefits from the personalization and rewording strategies. Subjects were 68 second-grade students and 59 fifth-grade students from two schools in the same school district in southeast Arkansas. Subjects were grouped into low-, medium-, and high-ability groups by ranking with the Metropolitan Achievement Test (MAT).

Prior to treatment, students were given a biographical questionnaire to complete (Davis-Dorsey et al., 1991). Eight forms of a 16-item problem-solving instrument were designed for each grade, each containing four instances of four problem types. The four types were change-change unknown, change-start unknown, combine-subset unknown, and compare-difference unknown. Each of the 16 problems was represented as one of four wording-context variations: standard wording-standard context, standard wording-personalized context, rewording-standard context, and rewording-personalized context. The test forms were randomly selected for individuals. The internal consistency reliability coefficients, computed by means of Cronbach's alpha formula, ranged from .82 to .93.

The result of this study indicated that the younger, less experienced second graders performed best when personalization and rewording were used in combination (Davis-Dorsey et al., 1991). That is, personalization did not prove to be beneficial for standard-wording problems, whereas rewording was not beneficial for standard-context problems. In comparison, the more experience fifth grade subject benefitted from personalization for both reworded and standard problems, but not from rewording for either context. These findings were consistent with the two Ross and Anand studies (Ross & Anand, 1987; Anand & Ross, 1987). Such strategies as rewording and personalization thus appeared to be useful for the improvement of problem-solving performance by helping learners comprehend the semantic structure of the problems and form correct problem representations. These benefits would seem especially important in the primary grades when children are first developing strategies for and attitudes toward solving word problems. However, once again, while the materials were generated by computers, subjects could only read the materials on paper and did not interact with computers.

The studies reviewed in this section were all conducted by Ross and his associates, and the concepts centered upon the contexts presented to the learners provided useful findings. First, the manipulation of familiarity in terms of the relationship of themes to student backgrounds was important. Preservice teachers benefitted from education-related materials, whereas nursing students performed best when the contexts concerned medical applications. Second, the personalized-context group was superior to both the abstract- and concrete-context groups in the solution of verbal problems. Third, personalized contexts (i.e., embedding math rules in highly familiar and meaningful information) increased task motivation and comprehension, thereby serving as an enhancement to learning.

However, these studies provided certain drawbacks. In the Ross (1983) study, each sample was derived from classes in which the subjects reflected a common major, education or medicine, and were thus focused upon homogeneous groups of subjects while ignoring any diversity of interests in the educational area. The study subsequently conducted by Ross et al. (1986) posed two problems: Only four options were provided to fit a still inadequate diversity of interests, in addition to which all of the subjects in the first experiment were female. In the studies conducted in 1987 by Ross and Anand and Anand and Ross, the use of university-affiliated elementary schools as samples limited the generalizability of the findings. Moreover, the CAI program design did not allow technology to play a central role in the design or delivery of instruction, and the presence of the experimenter became the main control throughout the experiment. In the Lopez and Sullivan (1991) study, the generalizability of the study was limited to rural Hispanic students. Finally, Davis-Dorsey et al. (1991) focused only upon the test and not upon instructions. Thus, it would be useful to test interactive programs which automate the tasks of lesson preparation and administration.

Solving Mathematical Word Problems

To acquire knowledge of the cognitive process which students may implement when solving mathematical word problems, and particularly the problems experienced in various improvement approaches to word problem solving, seven studies dealing with solving mathematical word problems are considered in this section.

Mayer (1982) investigated how the structural properties of algebra story problems influenced student abilities to recall problems and how student knowledge of problem types (i.e., schemes) influenced their ability to recall problems. The primary reasons for conducting this research was twofold. First, numerous research studies have suggested that two processes are involved in solving story problems: 1) translations, or understanding the problem, as manifested in translating the words of the problem into an internal representation in memory, and 2) solutions, or applying the legal rules of algebra and arithmetic to this internal representation to deduce an answer. Mayer noted that it had also been suggested that the major difficulty lay in the translation phase, although most instruction focuses upon solutions. Second, evidence existed that translations are influenced by both the structural properties of propositions in the problem and by the learner's schema for the problem. If problems involving relational information were difficult to translate, then subjects should have experienced greater difficulty remembering relational propositions. If schemes were used to translate problems, then subjects should have recalled information that was relevant to schemes more easily than irrelevant information, and thus should have tended to produce coherent, solvable problems.

The first and second experiments used identical designs (Mayer, 1982). For each study, 24 undergraduates were recruited from the psychology subject pool at the University of California, Santa Barbara. The goal of the experiments was to determine which types of information (i.e. assignment proposition, relation proposition, question proposition or relevant fact) subjects remembered from standard algebra story problems. A set of problem sheets and a cued recall test were administered. After analyzing the data, it was found that the relation propositions were more difficult to remember than assignment propositions, and that subjects tended to recall relevant information better than irrelevant information.

In the third experiment, the author attempted to determine which types of information subjects used in constructing standard algebra story problems (Mayer, 1982). The subjects were 36 undergraduates selected from among the same population used for the first two experiments. After analyzing the data, it was found that when they were asked to make up problems, subjects included almost no relational propositions, with assignments outnumbering relations by a ratio of approximately 25 to 1. Mayer concluded that relational information is more difficult to mentally represent than other kinds of relevant story information, and that and students possess some basic schemes for processing story problems. However, the population which can be generalized in this study was limited to college students.

Cummins et al. (1988) conducted two experiments to test the hypothesis that much of the difficulty children experience with word problems can be attributed to difficulty in comprehending abstract or ambiguous language. This was test by requiring children to recall problems either before or after solving the same problems, and then generating the final statements for incomplete word problems. For the first experiment, 38 first grade children from the Boulder Valley School District served as participants, with each given 18 story problems as stimulus materials. Subjects were tested individually during school hours, all problems were presented orally, and each child was required to solve the problems without benefit of paper and pencil. The sessions were recorded on tape.

Following data analysis, Cummins et al. (1988) determined that the performance on numeric problems was higher than that on word problems and that the performance on word problems was primarily dependent upon successful comprehension. A computer simulation model, as was proposed by Kintsh and Greeno (1985) and Dellarosa (1986), was also employed for the solution of the word problems. After matching subject performances and the simulated performances, it was observed that the overall pattern of recall accuracy closely resembled that of word problem solution accuracy; that is, there was a strong relationship between solution performance and recall performance. This finding supported the hypothesis that language comprehension strategies played a central and a greater role in word problem solving than logical-mathematical knowledge. Reliance upon the latter would attribute children's solution difficulties to the absence of conceptual knowledge, or to the absence of the elaborate schemata required to solve the problems correctly.

In the second experiment, the participants were 36 second and 36 third grade children from the Jefferson County School system (Cummins et al. (1988). The stories used for testing were based on the same difficult problem types as those used in the first experiment. Problems were presented by placing a card in front of each child and reading it out loud, in tape-recorded sessions. The results of this experiment indicated that the subjects solved more problems correctly when solutions preceded recall than when they followed recall, and that the correct solutions were associated with accurate recall of the problem structure and with appropriate question generation. However, since oral testing was not usually practiced in normal classroom instruction, these results may lack generalizability. In addition, the function of computer simulation was not clearly stated in this study.

Lewis and Mayer (1987) examined student difficulties in comprehending relational statements in arithmetic word problems, such as "gas at Chevron is 5 cents more per gallon than gas at ARCO." Two experiments were conducted to investigate how the order of terms in relational statements affects comprehension and the representation of arithmetic word problems. In the first experiment, 96 college students were recruited from the psychology subject pool at University of California, Santa Barbara. Subject were given an instruction sheet and a 24-problem test and asked to write the complete solution processes for the arithmetic word problems which contained relational statements. Eight problem types were presented on the test: consistent addition (e.g., requires adding two numbers when the problems says "more"), inconsistent addition (e.g., requires adding two numbers when the problem says "less"), consistent substraction (e.g., requires subtracting the second number from the first number when the problem says "less"), inconsistent substraction (e.g., requires subtracting the second number from the first when the problem says "more"), consistent multiplication (e.g., requires multiplication of two numbers when the problem says "n times as many"), inconsistent multiplication (e.g., requires multiplication of two numbers when the problem says "1/n as many"), consistent division (e.g., requires division of two numbers when the problem says "1/n as many"), and inconsistent division (e.g., requires division of two numbers when the problem says "n times as many"). Each solution was scored as correct if the proper numerical answer was given; otherwise the solution was scored in one or more of the following error categories: 1) reversal error or a representation error, in which the numerical operation for the first step of the problem was reversed; 2) arithmetic error, or a computation in the first or second step of the problem carried out incorrectly; or, 3) goal monitoring error, in which the second step (e.g., a direct variation) of the problem was omitted.

The results of the experiment indicated that students were more likely to miscomprehend a relational statement when the required arithmetic operation was inconsistent with the statement's relational term, such as having to subtract when the relational term was "more than" (Lewis & Mayer, 1987). This effect was magnified when the relational term was marked (e.g., less than) rather than unmarked (e.g., more than). According to the Clark (1969) principle of lexical marking, unmarked or "positive" adjectives are stored in memory in a form that is less complex than that of their marked opposites.

In the second experiment, the subjects were 26 college students recruited from the same psychology subject pool used for the first experiment (Lewis & Mayer, 1987). Students were given information about two variables and asked to generate a statement expressing their interrelationship. Data analysis revealed that the proportion of subjects generating unmarked terms was significantly greater than the proportion of subjects generating marked terms. That is, students tended to produce relational statements by using unmarked rather than marked comparative terms.

Based on the findings, Lewis and Mayer (1987) suggested there was a need for students to receive more training in the skills of problem representation, particularly in the representation of relational statements. However, the type of skills needed was not noted, nor were the directions required train students in these skills. Both experiments were conducted in short time periods (i.e., 30 minutes for the first experiment and eight minutes for the second) and were narrowly focused upon word problem tests. It may be speculated that the short experimental time threatens the validity of the findings.

Lewis (1989) continued to work on the development and testing of a training program directed at the improvement of students' representation skills by comparing word problems with the use of a diagraming method based upon external notation, thus allowing representation accuracy to be easily checked. The participants for the pretesting phase were 299 University of California, Santa Barbara, undergraduates who volunteered in partial fulfillment of the requirements for an introductory psychology course. From this number, 96 subjects were selected on the basis of the commission of reversal errors and representation errors in the pretesting phase. Subjects were separated into three groups of 32 subjects: a) A diagram group, trained in both translation and the integration of information in compare-problem statements: b) a statement group, which received only translation training; and c) a control group, exposed to the same problem as the other groups, but without either translation or integration training.

Following the training sessions, subjects were given a 22-item posttest to assess the effect of training (Lewis, 1989). Results indicated that the subjects were more likely to miscomprehend inconsistent-language compare problems than consistent-language compare problems, and that the diagram group produced greater pretest-to-posttest gains, with respect to problem comprehension and the transfer of the new skills, than either the statement control groups. Apparently, diagram training had a positive effect upon the solution of compare word problems. However, since the study was conducted with college students, the question of the benefit of training for younger students remained.

Willis and Fuson (1988) developed and tested a technique, referred to as schematic drawing, to facilitate the ability to solve word problems. Three different types of schematic drawings were used in the word problem instruction: Change-Get-More and Change-Get-Less; Put-Together; and Compare. The Change-Get-More and Change-Get-Less drawing involved an initial state, a change state, and a final state. The basic drawing was used with these two types, and the different nature of the changes were represented by plus or minus symbols inserted by the child. The Put-Together drawing was a part-part-whole or part-part-all drawing. The Compare drawing contained both large and small quantities placed adjacent to one another to facilitate their comparison. Three quantities in each problem were given mnemonic labels. Children were to write the letter for each label on the known or unknown quantity in the problem and then enter the known quantities into the correct places in the drawing, which could then be used to determine a correct solution strategy.

Subjects were second-grade children from two public schools in a small city near Chicago (Willis & Fuson, 1988). One of the classes contained 24 students and was categorized by the teachers as children with high math ability (HA). The other class contained 19 children categorized as children of average math ability (AA). Pretest and posttest measured the effect of the schematic drawing technique. Training in the technique was administered between pretest and posttest. Upon analysis of the data, it was determined that there was a strong relation between a correctly filled-in drawing and a correct solution strategy; few correctly filled-in drawings led to incorrect solution strategies, and few incorrectly filled-in drawings led to correct strategies. It was also determined that both the HA and AA classes showed improvement between the pretest and the posttest in the selection of correct solution strategies and the determination of correct answers. Thus, it was concluded that the problem category labels and schematic drawings coulc be useful in helping children to distinguish among the different types of semantic word problems and, ultimately, in the solution of difficult conflict problems. Since the subjects were second graders, the question of the usefulness of this strategy for older students remained.

Fuson and Willis (1989) tested the effect of their schematic drawing approach a second time upon 76 second graders attending two schools in a small city on the northern border of Chicago. The subjects were grouped by mathematics achievements, with 28 high achievers (H/A) selected from one school, and groups of 26 high achievers (H) and 22 average achievers (A) from the second school. In the previously used pattern, pretests and posttests were administered to measure the effect of the schematic drawing approach and analysis of the data indicated that the use of schematic drawings to represent the structure of a problem was consistent with the way in which word problems could be successfully conceptualized and solved by children. It was determined that the drawings gave teachers and children a common vocabulary with which to discuss the full range of addition and substraction problems. However, the authors did not perform a strict statistical analysis of their data. The attitude of teachers toward the use of this technique, particularly from the viewpoint of time and efficiency, was uncertain.

De Corte, Verschaffel, and Win (1985) investigated the influence of rewording verbal problems for children's problem representations and solutions, based upon the hypothesis that for less able or inexperienced children, rewording verbal problems so that the semantic relations were made more explicit (i.e., without affect upon their semantic and/or mathematical structure) would facilitate construction of proper problem representation and, by extension, assist in finding correct solutions.

Four first-grade and four second-grade classes, a total of 89 and 84 children, respectively, participated in this study (De Corte et al., 1985). Two series, A and B, of six difficult word problems were constructed. In series A, the problems were stated in the usual form in which they appeared in first graders' textbooks and in most of the recent investigations of addition and substraction word problems. In series B, the same types of problems were reformulated so that the semantic relations between the sets were stated more explicitly and were thus more clear to young children. For both grades, half of the pupils were given series A first and series B one week later, and for the other half this order was reversed.

Following analysis of the data, it was determined that series B problems were solved with significantly greater ease than series A problems, and that the difference between the two series was much greater for the A-B group than for the B-A group (De Corte et al., 1985). It was concluded that this finding supported the research hypothesis, and it was suggested that textbook writers could appropriately reword math word problems to overcome some of the difficulties children experiences with learning to solve word problems. However, these findings were restricted to less able and younger students.

The studies reviewed in this section yielded useful findings. First, the major difficulty in the solution of word problems in mathematics lay in the translation phase. Second, relational information was more difficult to represent than other kinds of relevant information in a word problem. Third, students' performance on numeric problems was higher than their performance on word problems, and their performance on word problems was primarily dependent upon successful comprehension. Fourth, students were more likely to miscomprehend a relational statement when the required arithmetic operation was inconsistent with the statement's relational terms. Fifth, diagram training seemingly had a positive effect in solving "compare" word problems. Sixth, problem category labels and schematic drawings could be useful in helping children distinguish among the different types of semantic word problems and thus for the solution of conflict problems. Finally, rewording verbal problems so that the semantic relations were made explicit, without affecting the semantic and mathematical structures, facilitated construction of proper problem representation and, by extension, determination of correct solutions.

Some of the drawbacks to this research area should be cautiously examined. These studies cited were limited to particular populations, either at the college level or younger and special populations. In the Cummins et al. (1988) study, verbal problem solving was an unusual classroom practice, and the basis for the computer simulation was not clearly stated. Lewis and Mayer (1987) focused narrowly on word problem tests and their experimental time was relatively brief. Willis and

Fuson (1988), and Fuson and Willis (1989), failed to either construct or provide a strict statistical analysis.

Summary of the Literature Review

Across the entirety of the studies reviewed in this chapter, the following implications are derived.

1. Prior achievement measures can provide a useful basis for identification and adaptation of individual and instructional prescriptions. Students with low prior conceptual understanding do not use good learning strategies and make poor sequencing decisions when exposed to learner-controlled treatments; thus, younger and less able students can make greater progress when exposed to program-control treatments. High prior achievement students are able to function equally well in both treatments, however, this class of students is able to complete learning programs more quickly under the learner-control condition than under program-control.

2. An adaptive design strategy that uses premeasure (aptitude), pretest (prior achievement), and on-task performance (learning) data results in more effective concept learning than an adaptive model that uses only pretask (premeasure and pretest) data. Instructional adjustment of display time per individual learner directly influences concept learning in terms of time required, the number of interrogatory examples needed, and the level of classification performance achieved. Research findings also indicated that adapting the sequence, first to conceptual knowledge formation, and then to procedural knowledge development, improves efficiency for slow learners, who have difficulty either recalling or generating appropriate memory management processes.

3. A learner-control condition can be a valuable instructional management system for computer-based instruction, in particular, if students receive information

that continuously demonstrates their progress toward mastery of the objective (diagnosis) while providing meaningful advice on appropriate stimuli necessary to attain the objective (prescription).

4. Instructional feedback which contains both knowledge of results and explanation information results in better achievement than the provision of only knowledge of results where the effect is shown for both field-dependent and field-independent subjects. Within the CAI setting, the provision of adaptive or fixed feedback does not make a significant difference in children's mathematics anxiety or achievement levels. However, the use of CAI in comparison to traditional instruction methods, tends to alleviate various aspects of mathematics anxiety.

5. There were no significant effects for learning styles on performance using CAI learning programs. For CAI learning programs, students with an internal locus of control did not produce greater achievements or greater student efforts than students with an external locus of control. However, student motivations to study particular subject matters was enhanced by making the subject available on computers. There was a strong positive effect for the computer applications on students' continuing motivation.

6. The major difficulty in solving word problems in mathematics lies in the translation phase rather than the solution phase. Student performances on numeric problems was higher than their performance on word problems and their performance on word problems was primarily dependent upon successful comprehension. That is, language comprehension strategies play a central role in word problem solving. Relational information is more difficult to mentally represent than other kinds of relevant information in word problems and students possess some basic schemes for processing story problems. Students are more likely to miscomprehend a relational statement when the required arithmetic operations are inconsistent with the relational terms of statements.

7. Within the studies that attempted to prompt students' problem solving skills: a) Diagram training had a positive effect in solving compare word problems; b) the use of schematic drawings was a useful method for helping children distinguish among the different types of semantic word problems and the solution of conflict problems; and c) rewording verbal problems so that the semantic relations were made explicit, without affect to semantic and/or mathematical structures, facilitated construction of proper problem representations and the determination of correct solutions.

8. The relationship of themes to student backgrounds is important. Preservice teachers benefitted from education-related materials, whereas nursing students performed best when the contexts concerned medical application. The personalized-context group was superior to both the abstract- and concrete-context groups in solving word problems. Personalized contexts, in which problems were embedded in materials which was highly familiar and meaningful to the students, increased task motivation and comprehension, and thereby improved learning.

The following recommendations for further research are generalized from the research findings reviewed, as well as from the investigator's personal experience in computer software development and CAI.

1. An appropriate model should be constructed to test correlations between student individual differences and learning capacities. The model should include variables related to individual differences, namely prior knowledge, intellectual abilities, motivations, and learning styles, as well as to variables related to instructional designs, namely the pace of instruction, concept sequences, display time intervals, the numbers of examples, the presentations of examples, and the forms of feedback.

2. Appropriate adaptive teaching strategies should be developed for different aspects of individual differences and for different learning areas. In particular, the algorithms considered in the RSIS and by the Ross (1983; Ross et al., 1986) context

presentations are good examples. Similar or improved algorithms should be developed to investigate accommodation of individual differences.

3. The quality of computer software, especially for interactive multi-media programs, should be evaluated since this consideration plays an important role in CAI learning.

4. Multiple-dimension interactive factor designs should be constructed for assessment of the complexity of human characteristics.

5. Longitudinal research investigations should be undertaken. Learning is a continuously changing process, therefore, long term observation is necessary.

6. High level cognitive abilities should be investigated, to the extent of categorizing learning outcomes with respect to cognitive abilities at the comprehensive, application, analysis, synthesis, and evaluative levels as well as the knowledge level.

7. Additional qualitative research should be undertaken. The learning process is so complicated that quantitative designs cannot be expected to yield comprehensive information. Qualitative approaches, including interviews, case studies, adequate descriptions, and the investigation of attitudes, preferences, and motivations may be additional variables that should be considered in future research.

Chapter 3
DESIGN AND METHOD

Introduction

Solving word problems has been viewed as one of the major weaknesses in children's mathematics achievement (Cummins et al., 1988; Mayer, 1982; NAEP, 1979). A number of previous studies have concluded that individualized examples and personalized contexts would prove helpful for the solution of these types of problems (Anand & Ross, 1987; Lopez & Sullivan, 1991; Ross & Anand, 1987). The present study is confined to the effect of the use of individualized examples and personalized contexts for an interactive computer-based adaptive mode. Currently, a review of the literature has revealed no previous studies have been conducted which have examined the use of interactive CAI programs with individualized examples and personalized contexts.

To investigate the effects of using individualized examples and personalized contexts for a specific interactive and adaptive CAI mode, a two-phase research project was undertaken. In the first phase, an interactive CAI program encompassing specific adaptive effects for individualized examples and personalized contexts was developed. In the second phase, the effectiveness of the use of individualized examples and personalized contexts versus an abstract approach was investigated. Subjects were selected from four classes from two middle schools in Oregon. Each subject completed a biographical questionnaire and a pretest prior to treatment. Following the treatment, a posttest and a reaction questionnaire were used to measure the effects among these approaches.

Three parallel CAI versions for the translation of algebra word problems were developed: 1) abstract, 2) individualized, and 3) individualized/personalized. For the abstract version, example and practice problems were presented without the involvement of specific learner interests or experiences. For the individualized version, example and practice problems were selected and constructed based upon the interests and experiences of the learners. For the individualized/personalized version, example and practice problems were selected and constructed based on the interests and experiences of the learners, in addition to which biographic information on the learners was embedded into the problem contexts. The CAI learning task involved the translation of word problems into equations. The program was developed for the Macintosh computer, using the *HyperCard* programming language.

Selection of the Subjects

Typically, study of the solution of equations and the translation of word problems into equations is begun in eighth grade pre-algebra. For the current study, the sample (n=97) consisted of eighth graders drawn from four middle school pre-algebra classes, two each from middle schools in Albany, Oregon and West Linn, Oregon. West Linn is a suburb of the metropolitan area of Portland with a socio-economic strata predominantly middle-upper class in nature, while Albany is a small-sized, rural community with a socio-economic strata predominantly middle-lower class in nature. Schools were selected based on the requirement that a 15-Macintosh station classroom was available. Furthermore, it was determined that the subjects selected for the sample were familiar with the basic Macintosh operating procedure. Subjects were randomly assigned to one of three treatment conditions and administered the treatment individually via computers.

Procedures

The study was based upon a pretest-treatment-posttest experimental design. The experiment was conducted from November and to early December, 1991 at, respectively, the West Linn and Albany middle schools. Differences in curricular structure prevented the simultaneous completion of the experiments at the two schools.

For the experiments conducted at the West Linn middle school, biographical questionnaires were completed on November 18, 1991. Based upon a class list provided by the instructor, each student was assigned an identification code at random, designating assignments to one of the three treatment groups. The information from the biographical questionnaire was then embedded into the learning program for the individualized and individualized/personalized group. The pretest was administered on November 25, 1991. The following day, during school periods six and eight, the subjects completed the CAI treatment in approximately 45 minutes. The classroom instructor provided initial directions; during the class period, the instructor and the investigator monitored the class and provided support when required. The posttest and the reaction questionnaire were administered on November 27, 1991. This was immediately prior to the Thanksgiving vacation and 12 of the subjects were absent.

For the experiments conducted at the Albany middle school, biographical questionnaires were completed on December 6, 1991, and a system identical to that observed at the West Linn middle school was followed for assignment of subjects to treatment groups and preparation of the learning program for the individualized and individualized/personalized groups. The pretest was administered on December 10, 1991 during periods four and six, requiring approximately 45 minutes for subjects to complete the CAI treatment. The procedure for administration of the treatment was identical to the procedure used at the West Linn middle school. The posttest and the reaction questionnaire were administered on December 12, 1991; only one student was absent and failed to complete the posstest.

Instrumentation and Learning Materials

The instruments used for the current investigation included a biographical questionnaire, a three-version CAI program, two parallel forms of the pretest and posttest, and a reaction questionnaire.

Instructional Programs

Three parallel versions of an interactive CAI tutorial unit for the translation of word problems into equations was designed by the investigator during the summer of 1991. A panel of five experts, including two professors in the Department of Science and Mathematics Education at Oregon State University (OSU) and three classroom middle school math teachers, assisted in the identification of program objectives, clarifying the verbal representations of the problems and verifying that the program met the identified objectives. The lesson content focused on the translation of word problems into single-variable equations, then solving these equations using addition, subtraction, multiplication, and/or division. The content was adapted from standard eighth grade pre-algebra textbooks and workbooks for instruction in the solution of equations associated with word problems, as well as selected teacher-made materials for the same student classification.

The general format of the interactive tutorial included presentation of word problems with guided solutions (i.e., identifying requested and given information, and examining the single-variable equations) and practice problems. The word problem examples, instructional contexts, and the practice problems were varied for the following treatments:

1) For the abstract treatment, the example and practice problems were randomly selected from a pool of traditional questions, not to include particular learner interests or specific experiences. An example problem is provided in Figure 3.1.

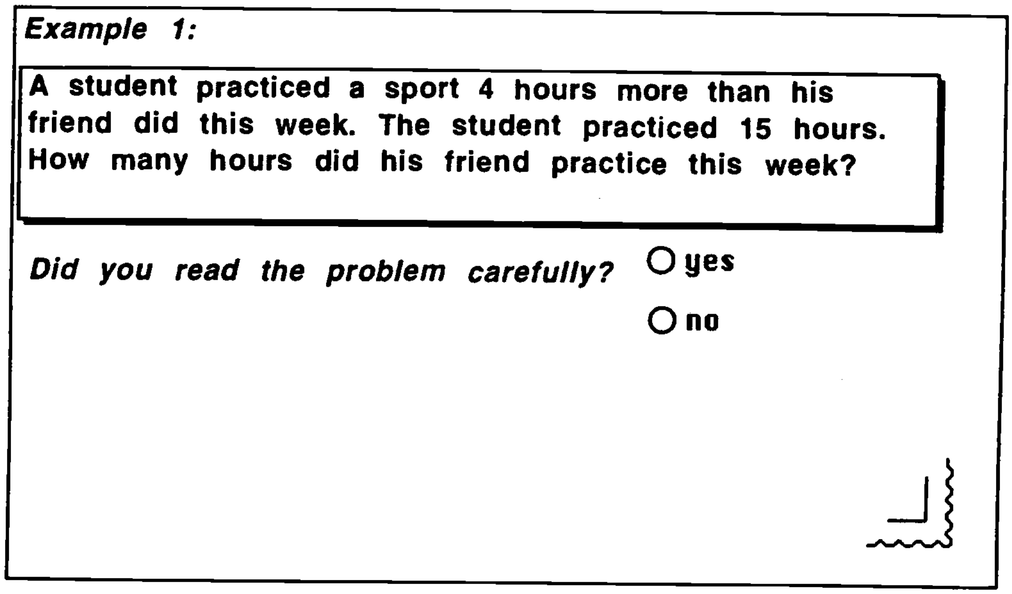

Figure 3.1 Example problem for the abstract treatment.

2) For the individualized treatment, the example and practice problems were selected and constructed based upon the individual interests and prior experiences of the learners. If the favorite activity of a particular subject was playing volleyball, then the example selected for the subject was presented as shown in Figure 3.2.

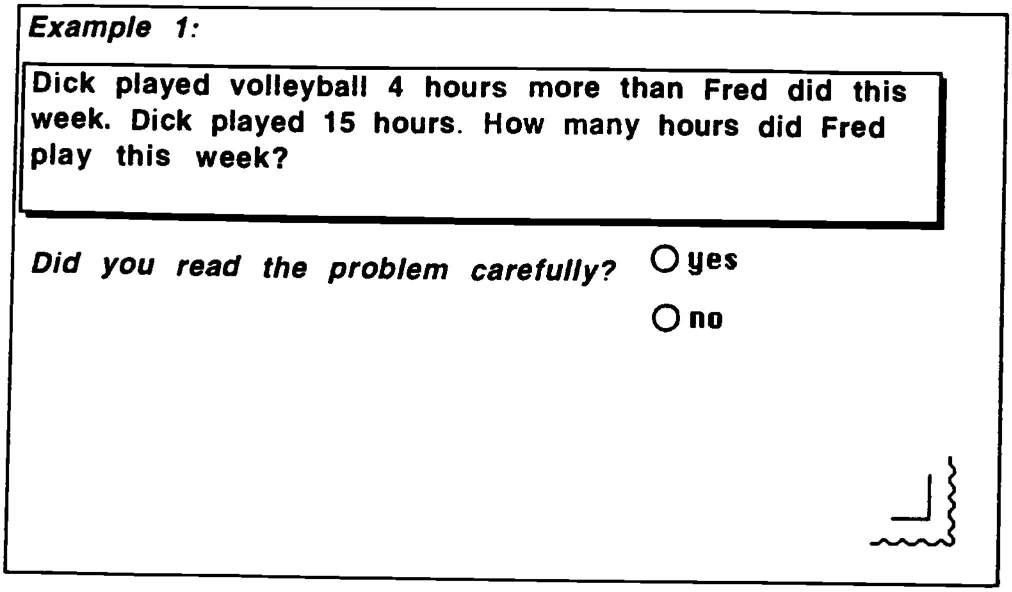

Figure 3.2 Example problem for the individualized treatment.

The template used for the individualized example was as follows:

> Dick *activity-verb-past activity-noun* 4 hours more than Fred did this week. Dick *activity-verb-past* 15 hours. How many hours did Fred *activity-verb* this week?

The value in activity-verb-past was "played"; the value for the activity-noun was "volleyball" and the value for the activity-verb was "play."

3) For the individualized/personalized treatment, example and practice problems were also selected and constructed based upon the individual interests and prior experiences of the learners. The difference between the individualized version and this treatment was, for the latter, that the example questions were revised automatically within the computer program by embedding the subject personal background data into the questions template. If the favorite activity of a particular subject,

Maggie, was playing Nintendo and one of her best friends was Norm, then the example selected for the particular subject would appear as shown in Figure 3.3.

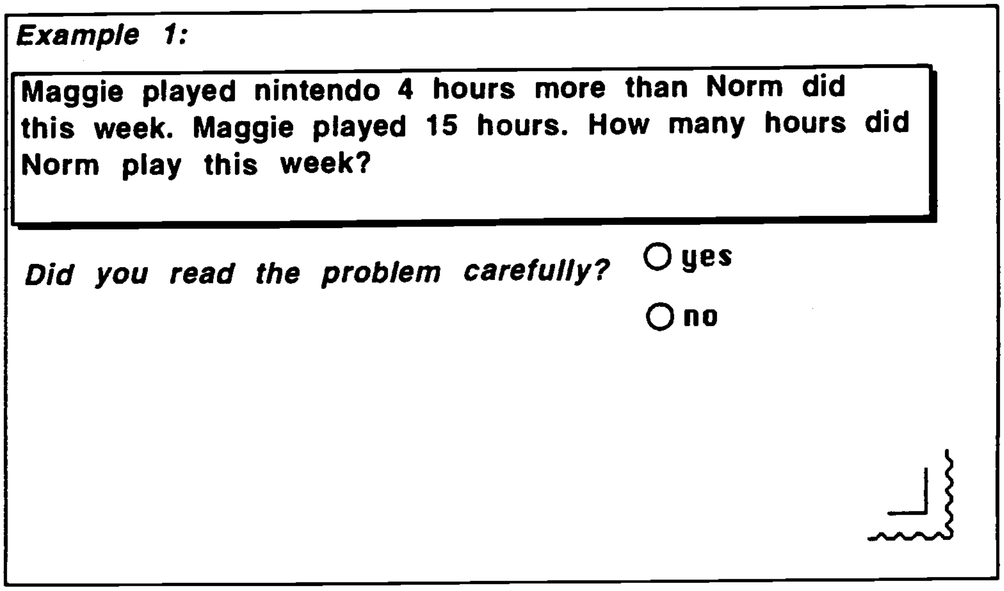

Figure 3.3 Example problem for the individualized/personalized treatment.

The template used for the personalized context was:

> *First-name activity-verb-past activity-noun* 4 hours more than *best-friend-1* did this week. *First-name activity-verb-past* 15 hours. How many hours did *best-friend-1 activity-verb* this week?

"Maggie" was the value placed in *first-name*; the value "played" was placed in *activity-verb-past*; the value "Nintendo" was placed in *activity-noun*; the value "Norm" was placed in *best-friend-1*; and the value "play" was inserted in *activity-verb*.

The program presented four examples, each of which was followed by a hint screen, a practice problem similar to the example from which the subject could learn to identify an equation from a word problem, a rule screen, and a practice problem from which the subject could learn to enter an equation from a word problem. Appendix A contains sample screens for each of the example problems.

For each example, the program assisted the subject in reading the questions, identifying variables, identifying relevant information within each problem, and constructing correct equations from the word problems. The hint screen was provided to assist subjects in the use of examples to solve similiar problems. For the identification practice mode, subjects were asked to select the correct equation from a multiple-choice set. The computer checked the answer and if an incorrect selection had been made, feedback including both a corrected response and helpful information specific to that incorrect item were shown. In the rule screen, subjects were assisted in the use of an appropriate variable to represent the arithmetic terms and entry of a correct equation. In the practice mode, subjects were asked to enter a correct equation via the keyboard, which was then checked by the computer for accuracy. Due to the variety of possible responses (e.g., $2n = 27 - 3$, $2n + 3 = 27$, $27 = 2n + 3$, or $3 + 2n = 27$), the computer checked equations stored in a database containing all of the possible forms for the correct equation. Subjects were given two opportunities to enter a correct equation. If the subject failed to enter a correct equation on the first try, the program allowed the subject to try again while providing no additional information; if the subject failed on the second try, the computer showed one of the correct equation possibilities and proceeded to the next example.

To assess subject performances for the three types of questions during the learning program exercises, responses were compared to the number of correct responses for the practice problems completed by the subject. Each time the subject has entered correct responses for both forms, the system added one to a counting variable which had been initialized at zero. The variable was placed in a hidden field, the "counter," on the last screen for review by the investigator.

Biographical Questionnaire

A questionnaire was prepared to obtain three information subsets regarding the interests, prior experience, and personal backgrounds of each subject (Appendix B). In the interests subset, favorite foods, sports, restaurants, activities, scholastic subjects, hobbies, and TV shows were surveyed. In the experience subset, subjects were asked about their experience with different types of transportation, if they had visited hospitals recently, the types of games they had played, the types of parties attended or other events they had experienced. In the personal background subset, the subjects were asked to identify their gender, family, siblings, relatives, teachers, and friends. This questionnaire required about 15 minutes to complete.

Pretest and Posttest

Parallel forms, designated A and B, of the evaluation instrument were used as the pretest and posttest instruments for the assessment of prior knowledge and learning outcomes (Appendix C). To reduce the instrumental effect, within each class, one-half of the subjects used Form A and the remaining half used Form B for the pretest; the use of these forms was reversed for the two halves for the posttest.

The tests consisted of two parts, each with six items. The first part involved the identification of an equation from a multiple-choice set. The following question is an example of this type of problem:

There are seven students on the honor roll.
This is three less than half the number in the class.
How many are in the class?

Let x = students in the class,
then the correct equation is

__ *(a) 2x-3=7*
__ *(b) 2x+3=7*
__ *(c) 3x+7=2*
__ *(d) 1/2x-3=7*

The second part asked the subjects to write the correct equation forms from word problems. The following question is an example of this type of problem:

There are seven students on the honor roll.
This is three less than half the number in the class.
How many are in the class?

Let x = students in the class,
then the correct equation is ____________.

Reaction Questionnaire

A paper-pencil questionnaire, consisting of eight 5-scaled items or open-ended items, as developed by Anand and Ross (1987), was used to survey reactions to the examples and to the lessons (see Appendix D). Some of the items consisted of statements to which respondents indicated levels of agreement or disagreement on a 5-point Likert-scale, ranging from, 1- Strongly Disagree to 5-Strongly Agree. Abbreviated descriptions of these items included: "examples were easy to understand," "examples were interesting," "examples were more understandable than in other units," "examples were easier to remember," "examples put me in the problem situation," "I enjoyed the lesson," "amount of material was sufficient," and, "lesson held my attention." The open-ended items on the questionnaire asked subjects to describe their feelings about the types of examples in the CAI program. Permission to use the attitude questions was obtained from the authors.

Validity and Reliability of the Instruments

The interactive CAI learning program was reviewed by an expert panel, as previously described in this section. An agreement level of 80 percent for each example or practice problem was the criterion for establishing content validity. If 80 percent agreement was not achieved for a particular problem, the problem was modified or revised and subsequent agreement was sought. A pilot study using the CAI program, based upon a selection of 10 students from a single class at approximately the same scholastic level as the subject sample, was conducted to determine the appropriateness of difficulty levels and learning times. Comments from the teacher and the students were used by the investigator to edit the CAI program.

The content validity of both the pretest and the posttest was also obtained by reference to an expert panel of five members, including one professor in the Department of Science and Mathematics Education at OSU and four classroom middle school math teachers. An agreement level of 80 percent for each problem was the criterion. If 80 percent agreement was not reached for a particular problem, it was revised or modified and subsequent agreement was sought.

In order to obtain equivalence reliability for the alternative test forms (Forms A and Form B), tests for internal consistency reliability and construct validity, as well as two pilot tests, were conducted. The first pilot test, based upon two pre-algebra (n=55) and three algebra classes (n=80) drawn from a middle school in Corvallis, Oregon, was conducted in October, 1991. The pre-algebra students were considered the inexperienced group, while the algebra students were considered the experienced group. The mean scores for the pre-algebra and algebra classes were, respectively, 7.5 and 9.3. This difference between the two groups was evaluated as significant at the level $p = 0.00$. However, for form equivalency, in which the pre-algebra students completed one form on the first day and the second on the following day, equivalence reliability was determined to be .59. Upon further consideration, it was determined that with only three parallel question types, this value was too low. Revisions were then made by inserting problems previously validated to assure a higher difficulty level. In November, 1991, a second pilot test was conducted, based upon a pre-algebra class (n=27) and an algebra class (n=20) drawn from a second middle school in Corvallis, Oregon. The mean scores for the pre-algebra and algebra classes were, respectively, 5.20 and 9.25. Equivalance reliability, as calculated by the Spearman Rank Correlation Coefficient, was .85.

Internal consistency reliabilities, calculated by KR21, were .73 and .68 for, respectively, the pre-algebra and algebra classes. However, consistency reliabilities during the experiment conducted with the subject sample were .52 for the pretest and .56 for the posttest. For reason of the low reliabilities obtained for the instruments, caution was exercised during interpretation of the findings of this study. Construct validity for the tests was obtained during the second pilot test of 50 students, of which 30 were pre-algebra and 20 were algebra students. The pre-algebra students were considered to be the inexperienced group, while the algebra students were considered to be the experienced group. The respective mean scores and standard deviations for the two groups was 5.20 and 2.98 compared to 9.25 and 2.38. It was determined that the difference between the two groups was significant at the level $p = 0.00$.

For the reaction questionnaire developed by Anand and Ross (1987), internal consistency was .75. The internal consistency reliability for the questionnaire adapted from Anand and Ross for the current investigation, calculated by the Cronbach alpha, was .73.

Data Collection

Following the assignment to a treatment, disks for administration of the experiment were distributed to each subject as identified by the assigned code. The instructional program was run on the Macintosh computer. Following collection of the biographical data, the computer program embedded these data into the instructional examples in accordance with specific treatments. The instructional program was administered during regular class periods. The investigator then inspected each subject's disk to display the hidden "counter" field identifying the subject's practice performance while using the program. On the day following this instruction period, the posttest and reaction questionnaires were administered. The scores for practice instruction, pretests, posttests, and the responses to the reaction questionnaire were analyzed using IBM *STATGRAPHICS* (1991), version 5.0.

Data Analysis and Hypotheses

Data were analyzed to assess three categories: 1) learning outcomes, 2) practice performance, and 3) reactions toward the lessons. Since the instructional materials were presented via computers, the subject were treated on an individual basis; therefore, the unit of analysis was the individual subject.

Learning Outcomes

An analysis of covariance (ANCOVA) was performed on the data for the assessment of learning outcomes, using the posttest as the dependent variable, the pretest as the covariate, and treatment, school, and class as the independent variables. Data was analyzed with respect to the following null hypotheses:

Ho_1: There are no significant differences in posttest scores among treatments.

Ho_2: There is no significant difference in posttest scores between schools.

Ho_3: There are no significant differences in posttest scores among classes.

Ho_4: There are no interactions in posttest scores between treatments and schools.

Ho_5: There are no interactions in posttest scores between treatments and classes.

Practice Performance

To assess the effect of the practice exercises for each treatment, an ANCOVA was performed to assess the subject performances for the different question types. The number of correct answers given for the practice exercises was the independent variable, the treatments were the independent variable, and the pretest score was the covariate. For analysis of this data, the null hypothesis was:

Ho_6: There are no significant differences in practice performances among treatments.

Reactions Toward the Lesson

After counting each subject's allocation of answers in the questionnaire, a two-way frequency table was used to compare the reaction differences among the three treatment groups. The frequency count was obtained by the scale for each question. Within the table, the three treatments were the row variables, while the scale intervals were the column variables. The expected values were counted according to the scale range. The χ^2 values for each question were then computed. The open-ended subject reactions served as descriptive inferences to the CAI instructions.

Chapter 4
ANALYSIS OF THE DATA

Introduction

The present study was conducted to investigate the effectiveness of the use of individualized examples and personalized contexts in terms of learning achievement, practice performance, and reactions toward the mathematics lessons administered via a CAI program. Raw data were analyzed with IBM *STATGRAPHICS* (1991), version 5.0. Since the data were incomplete, the results from this analysis did not reflect the scores of subjects who were absent on one of the pretest, posttest, or experimental days. Thus, 82 complete data sets were completed for this analysis. A significance level of .05 was used for all comparisons.

Results of the Data Analysis

The analysis was organized in three sections: 1) learning outcomes, 2) practice performance, and 3) reactions toward the lesson. For learning outcomes, three main effects, including treatment, school, and class, as well as interactions among the three main effects, were analyzed. Practice performance differences among the three groups may be considered as the difference in the solution of three different question types since each group was administered practice problems in the same manner as it was the example problems (e.g., the abstract group received abstract practice problems). Treatment reactions, measured by eight Likert-scale items, were analyzed; open-ended questions provided additional information.

Learning Outcomes

To test the first three hypotheses,

Ho_1: There are no significant differences in posttest scores among treatments,

Ho_2: There is no significant difference in posttest scores between schools, and

Ho_3: There are no significant differences in posttest scores among classes,

an ANCOVA was performed to test for learning outcomes using the posttest as the dependent variable, the pretest as the covariate, and treatment, school, and class as the independent variables. The ANCOVA adjusted subjects' posttest scores, based upon their pretest scores. For this analysis model, three factors (treatment, school, and class) were considered as variables affecting the posttest scores. Interactions between treatments and schools and between treatments and classes were also investigated. The results are shown in Table 4.1, which indicates that there were no significant differences among treatment ($F_{(2, 81)} = 1.06$; $p = .35$), school ($F_{(1, 81)} = 1.17$; $p = .28$), or class ($F_{(2, 81)} = 1.06$; $p=.35$). The only significant difference among these effects was the covariate ($F_{(1, 81)} = 73.42$; $p = .00$).

Additional detailed information, for means, standard deviations, and standard errors, is provided in Table 4.2. The order of the adjusted means was the individualized/personalized group ($M_{adj} = 6.87$), the individualized group ($M_{adj} = 6.34$), and the abstract group ($M_{adj} = 6.21$). However, the analysis showed no statistical differences among the three treatments. For the first hypothesis, the results supported the null hypothesis, that is, there were no differences in posttest scores among three treatments. School 2 ($M_{adj} = 6.69$) had a higher mean than School 1 ($M_{adj} = 6.25$). However, as indicated in Table 4.1, the statistical difference was not significant. For the second hypothesis, the results supported the null hypothesis, that is,

Table 4.1 Posttest ANCOVA, treatment, school, and class.

Source of variation	Sum of squares	DF	Mean squares	F-ratio	p
COVARIATE					
Pretest	232.79	1	232.79	73.42	.00*
MAIN EFFECTS					
Treatment	6.75	2	3.37	1.06	.35
School	3.72	1	3.72	1.17	.28
Class	6.73	2	3.37	1.06	.35
RESIDUAL	237.79	75	3.17		
TOTAL	496.31	81			

* $p < .05$.

Table 4.2 Means and standard errors for pretest and posttest groups.

		Pretest		Posttest			
Factors	N	M	SD	M_{unadj}	SD	M_{adj}	SE
Abs	30	4.97	2.17	6.17	2.39	6.21	.33
Ind	25	5.08	2.68	6.48	2.73	6.34	.36
Ind/per	27	4.74	2.33	6.74	2.38	6.87	.34
School 1	47	4.68	2.17	6.04	2.44	6.25	.26
School 2	35	5.26	2.60	7.00	2.45	6.69	.30
Class A	23	5.30	2.10	6.35	2.12	6.49	.47
Class B	24	4.08	2.10	5.75	2.72	6.27	.48
Class C	16	5.69	2.70	6.88	2.39	6.02	.53
Class D	19	4.90	2.51	7.11	2.56	7.50	.49
Overall	82	4.93	2.36	6.46	2.48	6.47	.20

Notes: N = number; M = mean; M_{adj} = adjusted mean; M_{unadj} = unadjusted mean; SD = standard deviation; SE = standard error for Abstract (Abs), Individualized (Ind), and Individualized/Personalized (Ind/per) treatments; School 1 = Classes A & B; School 2 = Classes C & D.

there was no significant difference between the two schools. The order of the adjusted means for the four classes were Class D (M_{adj} = 7.50), Class A (M_{adj} = 6.49), Class B (M_{adj} = 6.27), then Class C (M_{adj} = 6.02). However, as indicated in Table 4.1, there were no statistical differences among the classes. For the third hypothesis, the results supported the null hypothesis, that is, there were no significant differences among four classes.

For the fourth and fifth hypotheses,

Ho_4: There are no interactions in posttest scores between treatments and schools, and

Ho_5: There are no interactions in posttest scores between treatments and classes,

multiple factor analyses indicated there were no interactions between treatment and school ($F_{(2, 81)} = .57$; $p = .57$) or between treatment and class ($F_{(6, 81)} = 1.27$; $p = .28$).

Practice Performance

To test the sixth hypothesis,

Ho_6: There are no significant differences in practice performances among treatments,

an ANCOVA was performed for the number of correct responses, using practice results as the dependent variable, pretest results as the covariate, and treatment, school, and class as independent variables. For this analytical model, three factors, including treatment, school, and class, were considered as the variables affecting the practice performance. The ANCOVA for practice performance is shown in Table 4.3.

Table 4.3 Practice performance ANCOVA, treatment, school, and class.

Source of variation	Sum of squares	DF	Mean square	F-ratio	p
COVARIATE					
Pretest	14.29	1	14.29	31.21	.00*
MAIN EFFECTS					
Treatment	3.69	2	1.84	4.03	.02*
School	.31	1	.67	.42	.42
Class	.09	2	.04	.09	.91
RESIDUAL	34.34	75			
TOTAL	52.98				

* p < .05.

As indicated in Table 4.3, there were significant main effect differences for treatment ($F_{(2, 81)} = 4.03$; $p = .02$), whereas there were no significant main effect differences for school ($F_{(1, 81)} = .67$; $p = .42$) or class ($F_{(2, 81)} = .09$; $p = .91$). In addition, multiple factor analysis indicated there were no interaction effects between treatment and school ($F_{(2, 81)} = .91$; $p = .41$) or between treatment and class ($F_{(6, 81)} = .88$; $p = .51$). Since there was a significant difference among the treatment groups, a multiple-range analysis was used to check the contrast between each group. The means for the three treatments are provided in Table 4.4 to indicate additional analytical information. The practice performance score analysis was ordered by individualized/personalized ($M_{adj} = 1.48$), individualized ($M_{adj} = 1.41$), and abstract ($M_{adj} = 1.03$).

Multiple range analysis is shown in Table 4.5, indicating that significant differences existed between abstract and individual as well as abstract and individualized/personalized treatments; however, there was no significant difference between the individualization and individualized/personalized treatments. Thus, for Ho_6, the

Table 4.4 Means and standard deviations for pretest and practice scores for treatment groups.

		Pretest		Practice			
Factors	N	M	SD	M_{unadj}	SD	M_{adj}	SE
Abs	30	4.97	2.17	1.03	.76	1.03	.12
Ind	25	5.08	2.68	1.44	.77	1.41	.13
Ind/per	27	4.74	2.33	1.44	.85	1.48	.13
Overall	82	4.93	2.36	1.29	.81	1.31	.07

Notes: N = number; M = mean; M_{adj} = adjusted mean; M_{unadj} = unadjusted mean; SD = standard deviation; SE = standard error for Abstract (Abs), Individualized (Ind), and Individualized/Personalized (Ind/per) treatments.

Table 4.5 Multiple range analysis for practice exercises.

Treatment	Number	Least-squares mean	Group homogeneity	
Abstract	30	1.03	X	
Individualized	25	1.41		X
Individualized/ personalized	27	1.48		X

Notes: Method = 95% LSD; for group homogeneity, X's in the same column identify existence of significant differences between treatment groups.

results supported the alternative hypothesis; that is, significant differences were found in practice performance among three treatment groups, indicating that subjects in both the individualized and individualized/personalized treatments correctly answered a greater proportion of the practice problems than subjects in the abstract treatment group.

Reactions Toward the Lessons

The questionnaire consisted of two parts: Responses to the first eight items were based upon a Likert-type, five-point scale; the second part included open-ended questions. For the first part of the questionnaire, responses to eight five-point scaled items, Table 4.6 provides an assessment of reaction differences, based upon a count of scaled responses to each item, among the three treatment groups. Question items are included in Appendix D. Results indicated that there were significant differences among the treatments for Item 2 (χ^2 = 22.57, p = 0.04) and Item 5 (χ^2 = 15.65, p = 0.04). The response frequencies for Item 2 (i.e., "the word problems were interesting") and for Item 5 (i.e., "the word problems helped me to understand the problem-solving situations") are shown, respectively, in Tables 4.7 and 4.8.

Table 4.6 Chi-square values and levels of significance for reactions to the three treatments.

Item	Chi-square	D.F.	p
1	10.89	8	0.21
2	22.57	8	0.04*
3	11.21	8	0.19
4	12.71	8	0.12
5	15.65	8	0.04*
6	20.36	8	0.09
7	9.07	8	0.34
8	5.47	8	0.71

* $p < .05$.

Table 4.7 Response frequency, Item 2.

Treatment	1	2	3	4	5
Abstract	4	5	11	9	1
Individualized	0	4	9	12	0
Individualized/ personalized	1	4	3	11	8

Note: Columns 1 through 5 indicated scaled responses, from 1, "strongly disagree," to 5, "strongly agree."

Table 4.8 Response frequency, Item 5.

Treatment	1	2	3	4	5
Abstract	5	8	10	6	1
Individualized	2	6	8	7	2
Individualized/ personalized	6	1	12	7	

Note: Columns 1 through 5 indicated scaled responses, from 1, "strongly disagree," to 5, "strongly agree."

Thus, the results of response frequency analysis indicated that the individualized/ personalized treatment was attributed a higher proportion of scale points than either the individualized or abstract treatment groups for both Items 2 and 5.

The open-ended items in the second part of the questionnaire provided descriptive statements about subjects' reactions toward the lessons and the examples given in the CAI program. For the abstract group (n=30), three subjects indicated that they liked the lessons because they were challenging. Three subjects stated that they liked the lessons simply because they were able to learn them using computers. However, 14 subjects expressed difficulties understanding the word problems and translating the word problems into equations. Six subjects stated that the word problems were complex and confusing, while three subjects indicated that they felt either frustrated or lost. Three subjects wrote that the lessons were not fun and were boring.

For the individualized group (n=25), six subjects stated that the lessons helped them to solve problems in everyday life. Six subjects expressed feelings that the lessons were fun since they were administered by computers. However, seven subjects suggested that the lessons were hard to understand, while five subjects stated the lessons were boring or confusing.

For the individualized/personalized group (n=27), eight subjects stated that the lessons were fun and interesting. Six subjects expressed feelings that the lessons helped them understand word problems. Six subjects stated that they liked the lessons which used their names and personal information as parts of the learning context. Three subjects stated that the use of their personal interests and background information made the word problems more sensible and easier to understand. However, nine subjects still felt that the lessons were difficult, while four subjects suggested that the word problems were confusing.

Overall, for the open-ended questions, most of the subjects found that the lessons were difficult, regardless of their exposure to different types of examples and practice questions. It is noteworthy that a greater number of subjects in the individualized and individualized/personalized treatment groups indicated favorable responses to the lessons than subjects in the abstract treatment group.

Chapter 5
DISCUSSION AND CONCLUSIONS

The purpose of the current investigation was to develop an adaptive mathematics teaching model for an interactive CAI program and to evaluate the model effectiveness for the implementation of individualized example problems, or individualized example problems with personalized contexts. This study included both the development of the CAI module and an experimental phase. In this chapter, the experimental results and the limitations of the study are discussed, recommendations for future research are presented, and the implications of the study are considered.

Discussion of the Experimental Results

With respect to learning outcomes, the use of three different examples and learning contexts produced equivalent performances, with no significant posttest performance differences. The effects of the use of individualized examples and personalized contexts for the interactive computer mode were not found to be as useful as indicated in previous studies of non-interactive learning programs using only textual presentations (Anand & Ross, 1987; Lopez & Sullivan, 1991; Ross & Anand, 1987). Two possible factors could have served to distinguish the findings from the present study from those of prior studies.

First, it is possible that the interactive mode used for the present study decreased the effects of the individualized examples and the personalized contexts. The studies conducted by Anand and Ross (1987) and Lopez and Sullivan (1991) were not based on interactive programs. Rather, computers were used in these studies to either print out learning materials or to present contents on the computer screens. The subjects for both of these prior studies read the lesson contents silently on either paper or computer monitors. Seemingly, for these types of noninteractive programs, the use of individualized examples and personalized contexts served as important motivators. However, for the interactive programs used for the present study, all of the subjects were engaged throughout the lessons; therefore, motivation remained high among all of the treatment groups and the effects of the use of individualized examples and personalized contexts were less significant. It would appear that the use of individualized examples and personalized contexts provides a greater advantage for noninteractive modes than for interactive modes.

In the interactive mode developed for the present study, the CAI program included piece-by-piece presentations of concepts, step-by-step presentations of procedures for constructing equations, practice in identification and entry of equations, the elaboration of feedback, and appropriate control of the learner as well as the program. All these features are considered to be important to modern CAI programming and have been recommended for use by a number of prior studies. Gay (1986) stated that not all students are able to exercise effective control of learning programs; studies conducted by Roberts and Park (1984), Sales and Williams (1988), and Schloss et al. (1988) each suggested that the elaboration of feedback had a strong effect upon learning outcomes in CAI lessons. Tennyson et al. (1984) strongly advocated appropriate control of concept sequences and learning time through the instructional systems.

The second factor which serves as a possible explanation of the nonsignificant effects of the use of individualized examples and personalized contexts in the present study is that the lesson contents were deemed to be of higher than average difficulty for the subjects. In responses to the open-ended questionnaire, the subjects in all treatment groups expressed difficulty in understanding the problems. From closer examination of these responses, it was determined that most of the subjects were confused by the use of certain terms, for example, "3 more than," "4 less than twice," or "3 more than half of." Actually, these terms were crucial parts of the word problems.

Understanding the key terms (i.e., key words as well as key phrases) is more important than knowledge of other features of the problems. This point was confirmed by Cummins et al. (1988), to the effect that children found problems difficult because they could not interpret key words or phrases in the problem text. Cummins cited an example from Hudson (1983) as follows: "There are 5 birds and 3 worms. How many more birds are there than worms?" For many children, this type of problem is difficult, with correct performances ranging from 17 percent for nursery school children to 64 percent for first graders. A dramamtic improvement in solution performance on this type of problem was found when the final line was changed to the following: "How many birds won't get a worm?" Correct performance on this version of the problem ranged from 83 percent for nursery school children to 100 percent for first graders. It was concluded that "minor wording changes [were necessary] to improve solution performance" (p. 408). However, Hudson's change was not minor. The structure and logic between the two versions were quite different and the change in the final line of the problem text made a major difference in the problem situation. However, for the present study, only specific items were adapted in some manner and changes involving statements such as "more than" were not effected.

It seems that possessing schemata and logical knowledge, as well as language comprehension, are important to the solution of word problems. Fuson and Willis (1989) showed that the schematic drawing could facilitate the ability to solve word problems. Mayer (1982) demonstrated that translation was influenced by both the structural properties of propositions in the problem and by the learner's schema for the problem. Riley et al. (1980) considered that children's difficulties in solving word problems stemmed from a lack of conceptual knowledge or the elaborate schemata required to solve the problems correctly. Most of the children had difficulty in realizing the semantic meanings of crucial terms. This concept is similar to that expressed by Kintsch and Greeno (1985), to the effect that a problem solver could read and comprehend problem text without the ability to understand the mathematical situation for a problem. Hence, this student would not be able to derive an accurate solution equation.

The treatment effects for the practice performance were significant. The individualized and individualized/personalized groups answered correctly a significantly greater number of practice problems than the abstract group. The difference between the individualized and the individualized/personalized groups was not significant. In the program, each of the three treatment groups were asked to solve one of three different question types, directly after proceeding with similar examples. The results indicated that the subjects in the individualized and the individualized/personalized groups performed better on the practice problems than the subjects in the abstract group.

These findings suggest that when logical-mathematical knowledge remains in subjects' short term memories, the benefits of individualized examples and personalized contexts can be significant. While the subjects were solving the practice problems provided immediately after the instructional examples, they were provided with hint and rule support. Thus, they had no difficulty with the schemata of the key terms of the problems. Then, as they proceeded, different contexts became more important and significant differences were found. It is possible that the effects of individualized examples and personalized contexts were significant only when the subjects were provided with conceptual knowledge immediately prior to testing sessions. The effects were not significant for the one-day delayed posttest.

Reactions to the treatments were consistent with prior studies (Anand & Ross, 1987; Lopez & Harper, 1989; Ross & Anand, 1987), in which it was claimed that subjects favored individualized and personalized examples for some items. Most of the responses to the question items were not significantly different, and significantly different responses were indicated for only two items. When asked whether "the word problems were interesting" or whether "the word problems helped him/her understand the problem-solving situations," subjects in the individualized/personalized group were in greater agreement than subjects in the individualized or abstract groups. For the open-ended questions, subjects stated they were more serious and task-oriented when receiving the CAI programs. Similarly, Ross and Anand (1987) had stated that, "enthusiasm and interest also seemed higher under CAI" (p. 160). For the present study, the subjects had fun and were interested in the CAI lesson, especially those in the individualized and individualized/personalized groups who showed more positive attitudes when their personal interests or names were displayed on the learning screens.

Limitations of the Study

The primary limitation of the present research resulted from the short treatment period. The 45-minute period of learning time was too brief to deal with a complicated cognitive process, such as translating word problems, when not accompanied by additional instruction. It was observed that several students were not able to complete the four examples and eight practice questions within the 45-minute period.

Using *HyperCard* to develop the CAI program resulted in a reasonably good application; however, the program ran smoothly only when the *HyperCard* system was installed on the computer hard disk or when there were two disk drives from which *HyperCard* commands and application commands could be executed simultaneously. At one of the schools, where the computer was equipped only with one drive and no hard disk, frequent switches between the system disk and the application program had to be made. This action delayed the normal program run-time and may have distracted some of the subjects. Fortunately, the teacher managed the class well and most of the students were able to follow the directions.

A second limitation of the study lay in the process of determining what personal data, for each of the learners, should be embedded into problem situations. Difficulties arose from the issue of the kind of data to be inserted and the number of variables to be used to differentiate the three types of problems: That is, the more information put into the problems, the greater the difference between either individualized and abstract or between individualized/personalized and abstract treatments. Moreover, as more information was added to problems, additional time was required to manipulate the program. For example, if the embedded value was a verb, the tense of that verb (i.e., present or past) had to be considered everywhere throughout the problem, as well as the number (i.e., singular or plural) of a noun variable.

The capacity of the problem situations was another issue. The amount of personalized information which could be embedded into the problem situations was limited by considerations of fairness to each of the three groups and the appropriateness of using each of the variables in the word problems. It is possible that the personalized information used in the present study was insufficient to discriminate among subtle learning outcomes for this group of subjects.

Lack of learning incentives may also have been a problem. Since no grade incentives were involved, some students did not concentrate on the lessons and tests. Some subjects merely wanted to finish the lesson as soon as they could, regardless of the learning contexts. In addition, some subjects may have been bored since they had been exposed recently to similar types of tests. At one school, the posttest was held on the day prior to the Thanksgiving holidays and 12 students were absent. Some students did not complete the test; others, including subjects who had performed well on their pretests, confined themselves to arbitrary answers.

Based upon the apparent difficulty of the lessons and the small instructional gains achieved, the testing instrument may have been the ultimate limitation. In the parallel form based upon pretests and posttests, the absence of individualized questions and personalized contexts may have served to favor the abstract group. For the present study, tests with three different question types were considered. However, it was necessary to keep the test at an appropriate length. Thus, it was difficult to establish the validity and reliability of the test instruments for the pilot test since the variety of both questions and contexts was limited. Embedding information for all three groups took a great deal of time and changing test forms between pretests and posttests would have been confusing.

Recommendations for Future Research

Since a 45-minute treatment period may be too short, it would be reasonable to test the same problem over a longer period of time. This suggestion could be implemented in two ways. First, allow additional time to learn the same topics by developing a longer CAI program, one which could then be used in two or more periods of time. Second, the topic could be taught for an entire term or a school year. If this method was selected, then the CAI as well as other instructional strategies could be considered in combination. Strategies such as alternating lectures to interest-based groups, individual practices with computer-generated paper materials, and the use of individualized and personalized textbooks or worksheets could be included.

It would be worthwhile to investigate the differences between the use of non-interactive and interactive CAI modes. For the present study, only an interactive CAI lesson was developed and implemented and the results obtained differed from the study conducted by Ross et. al. (1987). The problem remains whether the interactive mode was the principal difference in terms of learning outcomes. This question should be subjected to further testing to measure the benefits of individualized examples and personalized contexts, either in a non-interactive mode, in an interactive mode, or both, or neither.

It is recommended that assessment instruments be developed for the simultaneous and joint evaluation of the performances of all three types of treatment groups. More information about each group's performance on the three different question types would be helpful. In addition, the study of the use of individualized examples and personalized contexts should be replicated for different grade levels and for different subject areas to assess the effects of these approaches during CAI adaptive teaching.

The instructional goals of algebra are considered to relate to the abstract representation of problems as equations. It is thus reasonable to worry about the overuse of individualized and personalized themes since students will eventually need to solve problems by means of abstract representation. Moreover, if all problems are couched in an individualized or an individualized/personalized manner, students may not be able to achieve a world-view of similar types of problems. This contention is worthwhile of additional study.

Since most of the subjects for this study stated that they were more serious and task-oriented while using the CAI program, the technological novelty of this approach remains a research topic of interest. In addition, it is recommended that the differences between standard classroom instruction or instruction by means of CAI lessons, or differences between personal instruction in combination with CAI lessons or in the absence of CAI lessons, be the subject of further review.

Implications of the Study

The development of the CAI program and the results of the experiment provided meaningful information about CAI design, learning theory with respect to cognitive processes, and math instruction imparted through word problems.

First, the development of an interactive CAI program for the present study demonstrated that with the availability of modern microcomputers and well-designed programming languages, such adaptive teaching effort can be put to practical use. For the present study, an interactive CAI program, "Translating Word Problems into Equations," based upon the use of a *HyperCard* authoring program was developed. Biographical information from individual students was embedded into problem templates for the individualized and individualized/personalized groups. The graphical icons for buttons, fields, and cards facilitated interactions between the learner and the program, allowing the learner to control some of the learning features, including pace and branching. The individualized examples and personalized contexts, the use of which produced better outcomes in practice performances and a number of interesting reactions, suggests further implementation of the use of this strategy for the design of CAI programs.

Corno and Snow (1987) stated that adaptive teaching is that which arranges environmental conditions to fit individual differences among learners. As learners gain in aptitude through experience with respect to the instructional goals at hand, this form of teaching adapts by becoming less intrusive. Less teacher or instructional mediation increases the learner information processing and/or behavioral burdens, and thus the need for more learner self-regulation. As the learner adapts, so also must the teacher. Truly adaptive teaching provides alternative instructional routes to different individual students to reach a common goal. In the present study, the common goals were to be able to understand abstract terms and thus, to be able to formulate equations and solve word problems correctly. In this approach, the teacher should make the instruction responsive to motivational or interest differences by providing a variety of materials and teaching strategies. However, when the same strategy is used throughout the period of instruction, the productivity of this approach may be subject to question. To adapt to interest differences, the teacher should build programs that are adaptive with respect to learning rates and individualized pacing to the greatest manifestations of cognitive aptitude differences. From the adaptive teaching viewpoint, it would seem to be ideal that teachers provide students with an equal opportunity to reach a common goal, despite individual differences in aptitudes, motivations, or personal backgrounds.

The present study reflects suggestions that the use of individualized examples and personalized contexts could help in the beginning phases of learning algebra. Following these phases, students should be able to learn how to use abstract terminology and how to formulate equations. At some level of adaptive teaching, as well as for the goal of solving algebra word problems, the learner will not always be able to rely on individualized examples and personalized contexts. The learner should be encouraged to reach an independent learning stage in order to overcome the barrier posed by abstractions.

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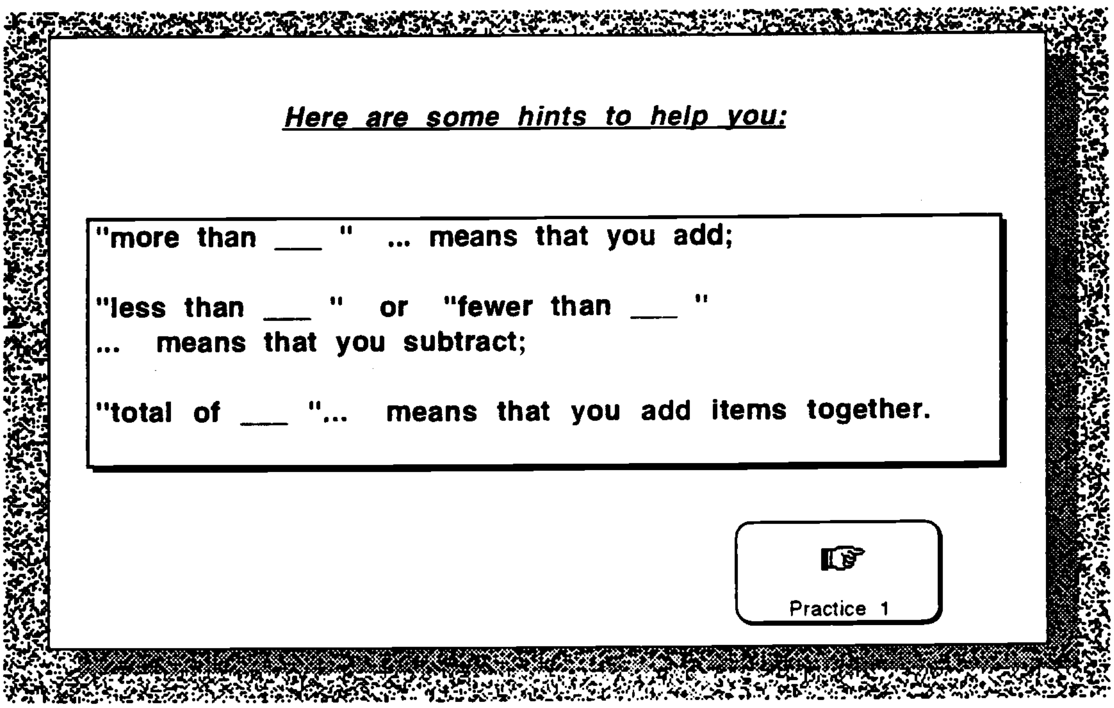
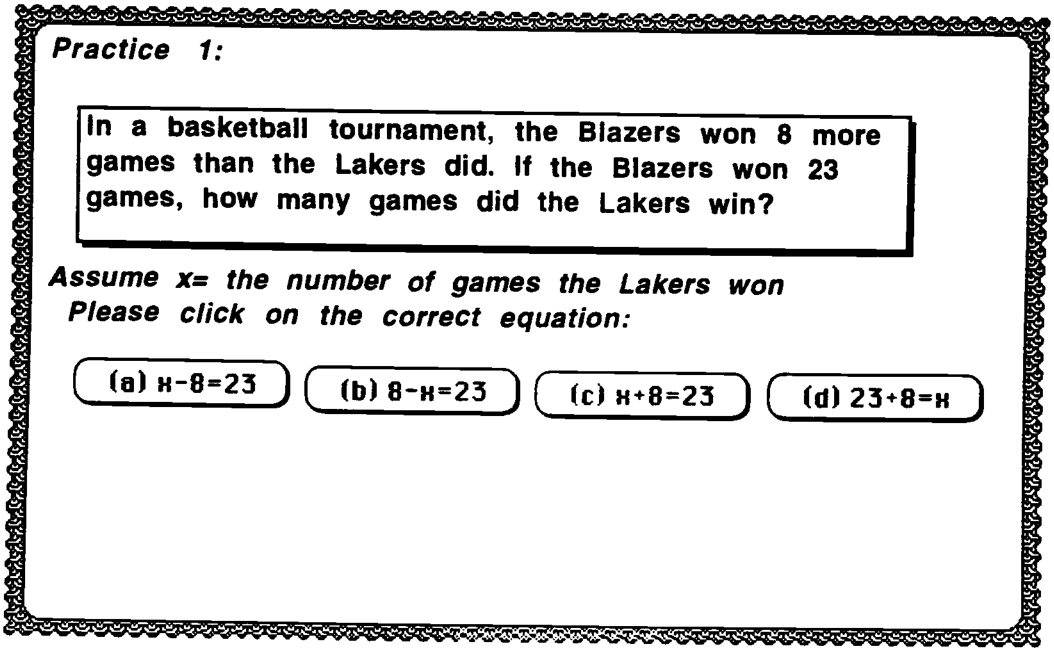
APPENDICES

Appendix A

Screens for Hints, Practice One, Rules, and Practice Two



Screen For Hints



Screen For Practice One

Maggie, when you enter equations,

DO use the following signs:	DON'T use spaces
+ addition	DON'T use $ for dollars
- subtraction	DON'T use * for multiplication
/ division	
() grouping	
= equal	
. decimal point	

Maggie, if the equation is x plus 5 equals 7 ,
then enter x+5=7.
Now, try entering the equation and hit return, please.

Screen For Rules

Practice 2:

Last month Dianne read 3 books less than Norm did on math. Norm read 14 books on math. How many books on math did Dianne read?

Let x=the number of books that Dianne read, then enter a correct equation and hit return:

....

Screen For Practice Two

Appendix B

Biographical Questionnaire

The purpose of this questionnaire is to obtain some information about your background and interests. The information collected in this questionnaire will be confidential.

Please write your answers into blanks:

1. Your first name is ________.

   Your last name is ________.

2. Your gender is ______ (female or male).

3. Your father's first name is ______________.

4. Your mother's first name is ______________.

5. Do you have any brothers or sisters? _____(yes/no)
   If yes, how many?________.
   What're their names?____________________

6. List your three best friends' names:

   __________ __________ __________

7. Name a classmate in your class that is not named in #6 above.

   ____

9. List your three favorite fast foods and where you eat them?

   For example:

<FOOD>	<WHERE>
Hamburger,	McDonalds;
Pizza,	Pizza Hut;
Fried Chicken,	Kentucky Fried Chicken, etc...

   __________ __________

   __________ __________

   __________ __________

10. What is your favorite soft drink?
    For example: Coca Cola, Pepsi, Root Beer, 7-up, etc...

    ____

11. What sports or games do you play often?
    For example: tennis, vollyball, soccer, Nintendo, Monopoly, etc...

    ___________ ___________ ___________

12. What sports do you watch and who are your favorite players or teams for those sports?

    For example:

<SPORT>	<PLAYER>	<TEAM>
Baseball,		Seattle Mariners;
Football,		San Francisco 49ers;
Basketball,		Portland Trail Blazers;
Tennis,	Jimmy Connors; etc...	

    ___________ ___________ ___________

    ___________ ___________ ___________

    ___________ ___________ ___________

13. Who is your favorite teacher this year and what course does he/she teach?
    For example:

<TEACHER>	<COURSE>
Mr. Smith,	Mathematics;
Mrs. Warren,	Music, etc...

    ___________ ___________

14. What is your favorite subject this year?
    For example: science, art, PE, music, etc...

    ____

15. Which class has the most tests this school year?
    For example: Mathematics, English, History, etc...

    ____

16. What do you like to do on the weekend?
    For example: Fishing, watching TV, traveling, shopping, etc...

    ___________ ___________ ___________

17. What are your hobbies?
For example: Collecting stamps, making models, collecting baseball cards, painting pictures, etc...

__________ ____________ _____________

18. What is your favorite movie?
For example: Little Mermaid, Home Alone, Robin Hood, etc...

____

19. What theater do you go to most often?

____

20. What kind of party have you attended recently?
For example: birthday, surprise, Halloween, etc...

____

21. What is your favorite tree?
For example: pine, oak, apple, cherry, etc...

____

22. What is your favorite flower or plant?
For example: marigold, rose, carnation, daisy, etc...

____

23. Name your 3 favorite small fruits?
For example: grapes, strawberries, cherries, blueberries, etc...

___________ ___________ _____________

24. Name 3 things you want most for your birthday present?
For example: bicycle, tennis racket, baseball glove, clothes, etc...

__________ ___________ _____________

Appendix C

Test Instruments

Form A:

Translating Word Problems

Student Number:____ Date:__________

PART 1

Directions: Select the correct equations by placing an "x" in front of a correct equation for the problem.

1. Susan jogged 2 fewer minutes than Brenda did. The sum of minutes they jogged was 58 minutes. How many minutes did Brenda jog?

Let t=time in minutes Brenda jogged.

_ a. t+2t=58
_ b. t+t=58
_ c. t+(t-2)=58
_ d. t+(t+2)=58

2. Rita had $21. After buying four pens, she had $3 left. How much did each pen cost?

Let n=the price of one pen.

_ a. 21.00-4n=3.00
_ b. 21.00+4=n
_ c. 4n-3.00=21.00
_ d. 4n=21.00+3.00

3. Some students at New Medford school sold 9 magazines a piece. The total amount sold by these students and the 125 magazines sold at another school, combined for a total sale of 161 magazines. How many students sold magazines at New Medford School?

Let x=the students sold magazines at New Medford School.

_ a. 9+125+x=161
_ b. 9x=161+125
_ c. 9+125x=161
_ d. 125+9x=161

4. A teacher bought 4 folders and 3 packages of colored pens in a store. One package of pens cost $2.50. The teacher paid $10.50 for the folders and pens. How much did one folder cost?

Let n=the price of one folder.

_ a. 3n+4(2.50)=10.50
_ b. 7n+2.50=10.50
_ c. 4n+3.00=10.50
_ d. 4n+3(2.50)=10.50

5. Mike has collected 4 fewer stamps than twice the number that Peter has. Together they have collected 64 stamps. How many stamps does Peter have?

Let y=the number of stamps that Peter has.

_ a. y+(2y-4)=64
_ b. y+2y=64
_ c. 2y-4=64
_ d. y+2y=4+64

6. Joel scored 5 more than half the number of points that Kyle scored in the basketball game. Together they scored 29 points. How many points did Kyle score?

Let k=the points Kyle scored.

_ a. k+(2k+5)=29
_ b. k+(1/2)k+5=29
_ c. k+k+2=29
_ d. (1/2)k-(k+5)=29

PART 2

Directions: Write an equation that uses the letter indicated in the problem.

7. When Shannon bought a tennis racket as Roger's Christmas present, she received a discount of $25 and paid $109 for the tennis racket. What was the original price of the tennis racket?

Let t=the original price of the tennis racket.

Then a correct equation is ________________

8. There are 32 doctors and nurses working in the Main Street Hospital. The number of nurses is 3 times the number of doctors. How many doctors work in the hospital?

Let w=the number of doctors.

Then a correct equation is ________________

9. A student has 4 nickels fewer than twice the nickels his sister has. He has 12 nickels. How many nickels does his sister have?

Let x=the number of nickels his sister has.

Then a correct equation is ________________

10. Jerry's bag of M&Ms has four more yellow M&Ms than Gail's bag of M&Ms. Together, they have 26 yellow M&Ms. How many yellow M&Ms does Gail have in her bag of M&Ms?

Let y=the number of yellow M&MS in Gail's bag.

Then a correct equation is ________________

11. Philip ate 7 strawberries more than twice the number of strawberries Ted ate. Philip ate 19 strawberries. How many strawberries did Ted eat?

Let n=the number of strawberries that Ted ate.

Then a correct equation is ________________

12. Kay received 38 points more than half Mary's score in the math test. Kay scored 81. What was Mary's score?

Let m=Mary's score.

Then a correct equation is ________________

Form B:

Translating Word Problems

Student Number:____ Date:__________

PART 1

Directions: **Select the correct equations by placing an "x" in front of a correct equation for the problem.**

1. Jimmy had $30. He bought four notebooks and had $2 left. How much did each notebook cost?

Let n=the price of one notebook.

_ a. 4n-2.00=30.00
_ b. 30.00-4n=2.00
_ c. 3n+2.00=30.00
_ d. 4n=30.00+2.00

2. Some students at Adams School sold 7 boxes of candy a piece. The total amount sold by these students and the 123 boxes of candy sold at another school, combined for a total sale of 165 boxes of candy. How many students sold boxes of candy at Adams School?

Let x=the students sold boxes of candy at Adams School.

_ a. 7x+123=165
_ b. 7x=165+123
_ c. 7+123x=165
_ d. 123-7x=165

3. Marisa swam 2 fewer minutes than Patty did. The sum of minutes they swam was 56 minutes. How many minutes did Patty swim?

Let t=time in minutes Patty swam.

_ a. t-(t+2)=56
_ b. t+t=56
_ c. t+(t-2)=56
_ d. t+2t=56

4. A student bought 3 quarter pounders and 2 glasses of Coke in a restaurant. One glass of Coke cost $0.75. He paid $5.90 for the the meal. How much did one quarter pounder cost?

Let n=the price of one quarter pounder.

_ a. 3n+2(0.75)=5.90
_ b. 5n+2.75=5.90
_ c. 3n+2.00=5.90
_ d. 5n+2(0.75)=5.90

5. Bob scored 4 more than half the number of points that Tom scored in the basketball game. Together they scored 28 points. How many points did Tom score?

Let k=the points Tom scored.

_ a. k-(1/2)k+4=28
_ b. k+k+4=28
_ c. k+k+2=28
_ d. (1/2)k+4+k=28

6. Sanford has collected 3 fewer baseball cards than twice the number that Kevin has. Together they have collected 54 baseball cards. How many baseball cards does Kevin have?

Let y=the number of baseball cards that Kevin has.

_ a. y-(2y+3)=54
_ b. y+2y=54
_ c. y+(2y-3)=54
_ d. y+2y=3+54

PART 2

Directions: Write an equation that uses the letter indicated in the problem.

7. When Tisha bought a pair of soccer shoes as Fred's birthday present, she received a discount of $17 and paid $46 for the shoes. What was the original price of the shoes?

Let p=the original price of the shoes.

Then a correct equation is ________________

8. There are 42 people working in a department store. The number of males is 5 times the number of females. How many females work in the store?

Let w=the number of females.

Then a correct equation is ________________

9. Kathleen received 25 points more than half Heather's score in the biology test. Kathleen scored 73. What was Heather's score?

Let h=Heather's score.

Then a correct equation is ________________

10. Farmer Jones has 3 horses fewer than twice the number of horses his neighbor has. Farmer Jones has 15 horses. How many horses does his neighbor have?

Let x=the number of horses his neighbor has.

Then a correct equation is ________________

11. Frank has 3 more marbles in his bag of marbles than John has in his bag. Together, they have 35 marbles. How many marbles does John have in his bag?

Let m=the number of marbles in John's bag.

Then a correct equation is ________________

12. Dianne ate 8 grapes more than twice the number of grapes Gerald ate. Dianne ate 24 grapes. How many grapes did Gerald eat?

Let n=the number of grapes that Gerald ate.

Then a correct equation is ________________

Appendix D

Reaction Questionnaire

YOUR REACTIONS TO THE LESSON No _______

Below are certain statements which relate to the lesson on "Translating Word Problems into Equations". Please read each statement carefully. At the end of each statement, use the rating scale: Strongly Agree, Agree, Undecided, Disagree, and Strongly Disagree.

Based on your personal reactions to the statement, please darken the square under the appropriate column.

Remember to read each statement carefully and mark only ONE answer.

STATEMENT	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1. The word problems were easy to understand.	☐	☐	☐	☐	☐
2. The word problems were interesting.	☐	☐	☐	☐	☐
3. I understood the word problems in this lesson better than the ones in other lessons.	☐	☐	☐	☐	☐
4. The word problems used in this lesson were easy to remember.	☐	☐	☐	☐	☐
5. The word problems helped me to understand the problem-solving situations.	☐	☐	☐	☐	☐
6. I enjoyed working on the lesson.	☐	☐	☐	☐	☐
7. There were enough practice problems for learning the materials.	☐	☐	☐	☐	☐
8. I paid more attention to the word problems than I usually do.	☐	☐	☐	☐	☐

Please answer the following questions briefly.

(1) How do you react when you read the word problems in the lesson on "Translating Word Problems into Equations"?

(2) Do you like to have math problems of this type in your classes?
Yes: ___ No: ___

(a) If so, in what way would it be helpful to have such problems?

(b) If not, why would you not want such math problems?

(3) Were you interested in the word examples?
Yes: ___ No: ___

Please feel free to write whatever you want to in the following space with regard to the lesson.

Thank you very much for your cooperation.