# DOCUMENT RESUME

ED 297 998 SE 049 632

| | |
|---|---|
| AUTHOR | Rowland, Paul McD. |
| TITLE | The Effect of Mode of CAI and Individual Learning Differences on the Understanding of Concept Relationships. |
| PUB DATE | 6 Apr 88 |
| NOTE | 46p.; aper presented at the Annual Meeting of the International Association for Computing in Education (New Orleans, LA, April 6, 1988). |
| PUB TYPE | Reports - Research/Technical (143) -- Speeches/Conference Papers (150) |
| EDRS PRICE | MF01/PC02 Plus Postage. |
| DESCRIPTORS | *College Science; *Computer Assisted Instruction; *Computer Uses in Education; Elementary Education; Elementary School Science; *Energy Education; Higher Education; *Preservice Teacher Education; Science Education; Teacher Education |
| IDENTIFIERS | *Science Education Research |

ABSTRACT

The effect of mode of computer-assisted instruction (CAI) and individual learning differences on the learning of science concepts was investigated. University elementary education majors learned about home energy use from either a computer simulation or a computer tutorial. Learning of science concepts was measured using achievement and applications tests. Four individual learning differences were measured including: (1) discrimination skill; (2) field orientation; (3) locus of control; and (4) learning strategy. Achievement test scores were higher for tutorial users than for simulation users but no difference was found for the applications test. Discrimination skill interacted with mode of CAI on both tests. Increased discrimination skill increased scores of tutorial users but decreased scores of simulation users. Increased external locus of control produced a decrease in score on both tests. Holistic learning strategies were superior to serialist strategies on the applications test. Field orientation had no influence on test scores. (A list of 26 references is included.) (Author/CW)

# The Effect of Mode of CAI and Individual Learning Differences on the Understanding of Concept Relationships

Dr. Paul McD. Rowland
Department of Science Education
East Carolina University
Greenville, NC 27858-4353

Paper presented at the Annual Meeting of the International Association for Computing in Education

April 6, 1988 New Orleans, LA

# Abstract

The effect of mode of computer-assisted instruction and individual learning differences on the learning of science concepts was investigated. University elementary education majors learned about home energy use from either a computer simulation or a computer tutorial. Learning of science concepts was measured using achievement and applications tests. Four individual learning differences (discrimination skill, field orientation, locus of control, and learning strategy) were measured. Achievement test scores were higher for tutorial users than for simulation users but no difference was found for the applications test. Discrimination skill interacted with mode of CAI on both tests. Increased discrimination skill increased scores of tutorial users but decreased scores of simulation users. Increased external locus of control produced a decrease in score on both tests. Holist learning strategy was superior to serialist strategy on the applications test. Field orientation had no influence on test scores.

# The Effect of Mode of CAI and Individual Learning Differences on the Understanding of Concept Relationships

## Introduction

An important task of educators is to help learners develop conceptual connections. Some science educators have suggested that the development of concept relationships can be enhanced through the use of computer-based simulations (Heinze-Fry, Crovello & Novak, 1984). Although meta-analyses have shown both computer-based tutorials and computer-based simulations to be effective means for improving instruction (Kulik, Bangert & Williams, 1983; Wise, 1987), it is not clear whether either mode is superior to the other for any particular type of instruction. For the purpose of this research, a tutorial is defined as a mode of computer-assisted instruction (CAI) that presents the concepts and rules of subject matter and evaluates the user's comprehension. A simulation is a mode of CAI that embodies a model representing some aspect of the real world and allows the user to manipulate variables in that model and observe the effects of those manipulations. At an analogical level, a tutorial is similar to didactic instruction while a simulation is similar to inquiry-based learning.

In addition to questions of the direct effect of instuctional mode there is also a question of interaction between mode and learning or cognitive styles. The aptitude-treatment-interaction (ATI) studies described by Cronbach and Snow (1977) indicated that individual differences in learning style interacted with instructional treatments; that is, some types of learners responded differently than others to particular instructional treatments. Although some researchers have investigated the effect of individual differences on CAI (Baird & Koballa, 1986; Pask & Scott, 1972; Shaw & Okey, 1985; Post, 1984), only a few studies have documented an interaction of individual learning differences with mode of CAI. Wesley (1984) found a sigificant interaction of locus of control with instructional mode (programmed instruction vs. CAI). Likewise, McLaughlin (1983) found an interaction between locus of control and mode of CAI (expository vs. discovery). Farkes (1985) found field orientation to interact with the concept learning strategy format of CAI; however, Dahl (1985) found neither main effects nor interactions with field orientation when he compared drills and simulations. Pask and Scott (1972) showed that the learning strategy construct they described in holist/serialist terms interacted with type of CAI instruction.

Rowland and Stuessy (1987) described a pilot study that indicated that certain types of learners (i. e., those who demonstrated field independence, external locus of control, high discrimination skill, and low memory skill) did particularly poorly when using a simulation. In addition, they showed that the matching of holist learners with simulations and serialist learners with tutorials produced significantly greater achievement than mismatching.

Despite the aforementioned findings, it is not clear how learning styles might interact with the mode of CAI.

## Purpose of the Research

This study sought information that would help teachers and software developers understand how CAI could assist learners in developing a greater understanding of concepts by (1) determining whether computer simulations are superior to tutorials in helping learners develop concept understanding as treatment and half to a simulation treatment. The treatment consisted of working with a CAI program of the designated mode in the subject area of home energy use. Two programs were developed by the author to provide parallel levels of graphics, interaction, and decision-making. Differences between the tutorial and the simulation existed mainly in the areas of type of feedback to the user (information vs. data) and type of interaction (selection/response vs. variable manipulation). Eleven trained software evaluators at New Mexico State University and Eastern New Mexico University rated both programs as suitable for classroom use. Subjects were administered the Group Embedded Figures Test (Oltman, Raskin & Witkin, 1971), Rotter's (1966) Internal/External Scale, and the Learning Style Profile -- discrimination subscale (Keefe & Monk, 1986).

A 15-item multiple-choice test was used to assess achievement and a 15-item multiple-choice test was used to assess application of concepts. Both tests were developed by the author. The achievement test had been used in a previous study where it had an reliability (KR-20) of .74 (Rowland and Stuessy, in press).

treatment and half to a simulation treatment. The treatment consisted of working with a CAI program of the designated mode in the subject area of home energy use. Two programs were developed by the author to provide parallel levels of graphics, interaction, and decision-making. Differences between the tutorial and the simulation existed mainly in the areas of type of feedback to the user (information vs. data) and type of interaction (selection/response vs. variable manipulation). Eleven trained software evaluators at New Mexico State University and Eastern New Mexico University rated both programs as suitable for classroom use. Subjects were administered the Group Embedded Figures Test (Oltman, Raskin & Witkin, 1971), Rotter's (1966) Internal/External Scale, and the Learning Style Profile -- discrimination subscale (Keefe & Monk, 1986).

A 15-item multiple-choice test was used to assess achievement and a 15-item multiple-choice test was used to assess application of concepts. Both tests were developed by the author. The achievement test had been used in a previous study where it had an reliability (KR-20) of .74 (Rowland and Stuessy, in press).

Appropriate t tests, ANOVAs and regression analyses were conducted using the SAS package to detect statistically significant differences.

## Results

In this study, the effect of mode of CAI (MODE) was examined for its main effect and its interaction with four constructs of individual differences (discrimination skill, field orientation, locus of control, and learning strategy) on two dependent variables measuring concept understanding and application.

### Instrumentation

The Home Energy Achievement Test and the Home Energy Applications Assessment were author-created tests. Split-half reliabilities were calculated and adjusted using the Spearman-Brown technique. For the achievement test, the reliability was .67 while the reliability for the applications assessment was .54.

### Descriptive Statistics

Originally, 101 individuals agreed to take part in the study. Due to missing data, that number was reduced to 97.

The means, standard deviations, and ranges obtained for the instruments are shown in Table 1. As a result of the Study Preference Questionnaire, 34 subjects were classified as holists and 63 were classified as serialists using Ford's criteria (Ford, 1985).

Correlations

Correlations among the various instruments are shown in Table 2. Significant correlations include that of learning strategy (SERHOL) with the applications test (HEAA, *r* = .21) suggesting a higher applications score for holists. Correlation between the instruments measuring locus of control (LOC) and field orientation (FDI, *r* = -.34) should also be noted. The correlation between the two dependent variables (HEAT and HEAA, *r* = .36) was also significant.

Finally, the correlation of the mode of CAI (MODE) with Home Energy Achievement Test (HEAT, *r* = -.51) was indicative of a significant main effect of mode of CAI on that instrument.

Tests of Hypotheses

The first hypothesis predicted that the users of the tutorial would score higher on a multiple-choice achievement test than the users of the simulation.

Table 3 shows the results of the $t$-test comparing the effects of the two modes of instruction on the Home Energy Achievement Test score. The null hypothesis was rejected and the predicition supported.

The second hypothesis predicted that users of the simulation would score higher than users of the tutorial on a multiple choice applications test. Table 4 shows the results of the $t$-test on the scores of the Home Energy Applications Assessment. No significant difference between the scores of the two different modes was found. The null hypothesis was not rejected.

The third hypothesis actually consisted of four hypotheses dealing with the interaction of individual learning differences measures with mode of CAI. Because three (Learning Styles Profile -- Discrimination Skills subscale, Group Embedded Figures Test, and Rotter's I/E Scale) of the four measures of individual differences were continuous variables (Study Preference Questionnaire classifies subjects into two groups) a regression approach was used to partition the variance to detect the presence of interactions between individual differences and mode of CAI.

For each individual difference variable, two regressions were computed using the general model:

DV = B0 + B1(MODE) + B2(IDV) + B3(MODE*IDV)

where DV = the dependent variable (HEAT, HEAA),

B0 = an intercept term,

B1(MODE) = the effect of the mode of CAI (MODE is coded as a dummy varible),

B2(IDV) = the effect of the individual difference variable,

B3(MODE*IDV) = the effect of the interaction between the mode and individual difference variable.

<u>Discrimination Skill</u>. The individual difference variable, discrimination skill, was measured by the Learning Styles Profile Discrimination Skills subscale. Table 5 shows the analyisis of the variance due to discrimination skill for the two dependent variables.

Significant mode-by-discrimination skill interactions were found for both the achievement test and the applications test.

In addition, a main effect (*p* = .04) was found for discrimination skill on the applications test; that is, as discrimination score increased, score on the applications test decreased. However, the significant interaction with mode indicated that the relationship was [illegible] complicated.

To clarify the nature of the interactions, a plot of predicted values of the model was made for each of the significant interactions. Figure 1 shows the effect of discrimination skill on achievement test score (HEAT) for the two modes of instruction. The plot of predicted values of achievement test scores indicated that scores increased with discrimination skill for tutorial users and decreased with discrimination skill for simulation users. The examination of the estimates of the slopes for the two lines indicated that the slope for the tutorial line (.57) was significantly different from zero ($p$ = .022) while the slope for the simulation line (-.24) was not different from zero ($p$ = .162). Achievement test score increased with discrimination skill for tutorial users but discrimination skill did not influence the achievement test score of simulation users.

The interaction of discrimination skill and mode of CAI for the applications test is shown in Figure 2. In this case, the applications test score decreased with discrimination skill for simulation users while the score for tutorial users increased slightly with an increase in discrimination skill. Estimates for the slopes of the two lines indicated that the slope of the simulation line (-.63) was not equal to zero ($p$ = .001) while the slope of the tutorial line (.21) was not significantly different from zero ($p$ = .318). On the applications test, an increase in discrimination skill resulted in a decreased score for simulation users, but an increase in discrimination skill had no affect on the applications test score for tutorial users.

In summary, discrimination skill interacted with mode of CAI for both instruments, but the nature of the interaction was different for the two measures.

Locus of Control. The locus of control construct was measured using Rotter's I/E Scale. The analyses of variance of the concept understanding and application scores are shown in Table 5. Although no interaction terms were significant, it was noteworthy that the main effect of locus of control was significant for both tests. In both cases, the more external the locus of control was, the lower the score on the test.

Field Orientation. Field orientation was measured by the Group Embedded Figures Test. Table 6 shows the analyses of variance for the two dependent variables. No main or interaction effects were significant and the null hypothesis of no effect/no interaction for field orientation was not rejected.

Learning Stategy. Learning strategy was classified as holist or serialist on the basis of performance on the Study Preference Questionnaire using Ford's (1984) methodology. Dummy variables were used in the regression (serialist = 0 and holist = 1). The ANOVA is shown in Table 7.

Neither of the dependent variables showed an interaction of mode of CAI with learning strategy. A main effect of learning strategy on the applications test score was found. Holists performed better on the applications test than serialists.

## Discussion

The purpose of this study was to help practitioners and researchers improve their understanding of how CAI and its interaction with individual learning differences influences science concept understanding. In part, this research compared the effects of computer tutorial instruction to computer simulation instruction. In addition, the study examined four individual difference variables for their main effects and especially their interactions with mode of CAI on concept understanding.

A Comparison of Two Modes Of CAI

Two hypotheses were formulated to examine the difference in the effects of computer-assisted tutorial instruction and computer-assisted simulation instruction. Bell (1985) has argued that the various modes of instruction have different instructional formats because they are intended to teach different skills. She claims that tutorials teach concepts and rules, while simulations develop cognitive strategies. If this is true, then a fair comparison of the two modes should be based on evaluation instruments that examine the strengths of each mode. In addition, the evaluation instruments should allow the researcher to measure those variables deemed important to the discipline in question. To this end, two measures of science concept understanding were developed for use in this research. An achievement test was used to measure concept understanding at a variety of levels, and an applications test was used to evaluate the application of cognitive strategy to problems in the instructed content area.

Home Energy Achievement Test. It was predicted that the score on the achievement test would be higher for tutorial users than for simulation users. This prediction was based on the fact that the tutorial included "quiz" sections that were similar to the multiple-choice achievement test. Such sections would be common in tutorials designed using instructional design guidelines of Gagne, Wager, and Rojas (1981). The results of this research affirmed the predicted difference. The achievement scores of tutorial users were an average of 2.7 points or 35% higher than the scores of simulation users.

That tutorials are better instructors than simulations for achievement tests seems commonsensical. It is logical that a program which essentially includes practice on a measurement instrument should outperform a program that does not provide such practice. Moreover, since half of the achievement test consisted of lower level questions, recall was an important factor in determining the test score. Bell (1985) indicated that a tutorial should prepare the learner for this type of evaluation of concept understanding. The best conclusion to be drawn from these results is that the tutorial produced the expected outcome.

<u>Home Energy Applications Assessment</u>. The applications test was used in this study to provide a more direct measure of what the simulation was designed

to teach; that is, the use of cognitive strategies to solve problems. It was predicted that those subjects who had the opportunity to practice problem solving (the simulation users) would do better on the applications assessment than those who did not have such practice (the tutorial users). The results showed no significant difference.

These findings were surprising since this instrument had been constructed to measure the strengths of a simulation. The failure of the simulation to provide superior applications instruction could be interpreted in several ways. One problem may have been the simulation itself. One might consider the quality of the simulation used in this research. Although evaluators recommended this simulation for classroom use, the criteria for the evaluation of simulations are not well developed. Coburn et al. (1982) stated, "Well designed computer simulations combine graphics, animation, text, and a realistic problem to solve in a rich learning environment" (p. 31). Perhaps the attempt to make the tutorial and the simulation similar by limiting graphics and excluding animation deprived the simulation of its value.

Another explanation of the failure of the simulation might lie in the nature of the treatment. The treatment did not include instruction on how to use the computer program for learning. Consequently, subjects might not have explored the simulation in the way simulations are meant to be explored. Indeed, given the short amount of time (as little as 20 minutes) that some subjects spent on the treatment, one must suspect that in some cases little or no exploration of variables occurred. Although the instructions recommended that such exploration occur, it is likely that some subjects ignored that recommendation.

An alternative, related explanation lies in the nature of the subjects. Although data were not gathered on the computer experience and background of the subjects, the author could identify about half of the students as enrolled in a computer literacy course. In this course, the subjects had participated in tutorial CAI but few had any experience working with simulations. The lack of experience in working with simulations might have contributed to a lack of learning from this mode of instruction. Indeed, it might be tempting to argue that given the briefness of the treatment time, it is surprising that simulation users performed as well as they did. A reasonable conclusion is that the simulation is as effective as the tutorial in preparing students for a multiple-choice applications test.

CAI and Individual Learning Differences

A major thrust of this study was to determine how individual learning differences, directly and through interaction with modes of CAI, influenced concept learning and concept application. This influence is shown in Table 8.

Discrimination Skill. Keefe and Monk (1986) described the discrimination skill construct as meaning "to visualize the important elements of a task; to focus attention on required detail and avoid distractions" (p. 5). This portion of the Learning Styles Profile was developed on the basis of the psychological construct "cognitive control," referred to as "extensiveness of scanning" by Gardner and "focus/nonfocus" by Schlesinger (J. W. Keefe, personal communication, October 10, 1987). Gardner and Moriarity (1968) describe the construct as the subject's "capacity to direct attention selectively to relevant versus irrelevant portions of stimulus fields"

(p. 50). According to J. W. Keefe (personal communication, October 10, 1987), the test was developed to examine "how well subjects can ignore distracting information." High scorers focus on the important elements of the task, while low scorers fail to focus on the salient information.

The potential for this variable to interact with mode of CAI was demonstrated in a previous study (Rowland & Stuessy, 1987). The present research found that

discrimination skill interacted with mode of CAI on both dependent variables. On both measures, high discriminators did better if they used the tutorial. On the achievement test, the performance of extremely low discriminators (DISK=0) was not influenced by mode of CAI. The results of the applications test showed a higher score for simulation use by extremely low discriminators (DISK = 0), no mode effect for subjects with intermediate discrimination skill (DISK between 1 and 3) and a favoring of tutorial use by high discriminators (DISK of 4 or 5). The negative main effect of discrimination skill on the applications test was due to its influence on simulation users.

It was clear that high discriminators learned better from a tutorial. A decrease in discrimination skill trended towards a decrease in score for tutorial users but an increase in score for simulation users. The significance of that trend depended on the instrument used.

For practitioners, this finding suggested that the matching of high discriminators to tutorial instruction might enhance learning. Very low discriminators might learn more using simulations.

These findings were consistent with the difference in the nature of simulation use versus tutorial use. An effective user of the simulation should be attending to all of the information to notice the effects of interactions of variables. A tendency to "over focus" on a particular variable might lead to not perceiving changes in other variables. On the other hand, tutorials are constructed with the intent that the learner focus on the sequential presentation of information. Failure to focus might result in a failure to acquire information.

Although matching low discriminators to simulations and high discriminators to tutorials might enhance learning, a better approach would be to develop strategies that help low discriminators focus on tasks when it is appropriate and help high discriminators be less focused when it is appropriate. This challenge should be taken up by instructional designers at all levels.

Field Orientation. The finding that field orientation had no main effects or interactions was surprising. This construct was examined because it has been shown to be a strong determinant of scientific reasoning in adolescents (Stuessy, 1984). The previous study conducted by the author (Rowland & Stuessy, 1987) suggested that an interaction was likely in the present research. The results found in the present research confirm Dahl's (1985) finding of no significant main effects of field orientation or interactions with mode of CAI (drill versus simulation).

Locus of Control. Wesley's (1984) and McLaughlin's (1983) findings of interactions between locus of control and mode of instruction encouraged the use of this construct in the present research.

In this study, an increase in internality resulted in an increase in score on the achievement test and the applications assessment. This main effect of locus of control on the two tests might reflect a general problem of using CAI with externally motivated learners. If external motivation comes from human interactions, CAI might fail to provide that motivation regardless of its feedback mechanism. Consequently, externally motivated learners might not feel rewarded and might not learn as well from CAI as they would from human-based instruction. There has been an assumption among many software developers that feedback via the computer is more effective than human feedback because CAI feedback can be immediate (Doerr, 1979). For external individuals who require not the immediacy, but the humanness of the feedback, such claims might be false. Clearly, further research is needed in this area to identify under what circumstances locus of control influences learning from CAI. If it is generally true that external students have trouble learning from CAI, then alternative effective learning strategies need to be developed for these individuals. In addition, strategies to assist external learners in becoming more independent of human reward should be developed.

Learning Strategy. Pask's (1976) work on learning strategy served as the basis for studying this variable. The results of a previous study matching holists to simulations and serialists to tutorials suggested an interaction between learning strategy and mode of CAI (Rowland & Stuessy, in press). The failure to find an interaction was not expected. However, the higher applications test score of holists over serialists was not surprising. The application of information on home energy required the use of "chunks" of information that was not in the sequence presented. Serialists would have been less likely to reassemble the information in the way needed to solve the problem. Holists would have been more likely to have arranged the information globally so that it could have been more readily recovered for problem solving. This suggests an interesting research question regarding the use of rules in problem solving. Perhaps, serialists would be better problems solvers when rules can be invoked and holists better problem solvers when rules do not exist or are not known. In addition, it raises the question of what educators can do to help serialists become better at reformatting their knowledge so they can apply it in novel ways.

## Conclusions

Given the assumptions and limitations of this research, the following conclusions are supported by the data.

* When concept understanding is measured with an achievement test, tutorial CAI is superior to simulation CAI.

* When concept understanding is measured using an applications test, no significant difference is found between the two modes of CAI.

* The greater the externality of the learner's locus of control, the lower the demonstration of concept understanding on an achievement test and an applications test following CAI.

* Holists perform better than serialists on an applications test following CAI.

* Mode of CAI interacts with discrimination skill on both assessments of concept understanding such that in some circumstances the simulation mode is superior, in some circumstances the tutorial mode is superior, and in other circumstances neither mode is superior. These circumstances vary according to the assessment instrument used and the level of learner discrimination skill.

Implications

The purpose of this study was to help practitioners and researchers improve their understanding of how CAI and its interaction with individual learning differences can influence science concept understanding. The results of this study lead to recommendations regarding specific actions for both groups.

Teachers and instructional designers should recognize that some individuals will have problems learning from CAI. Serialists need special help in learning how to apply their understanding of concepts to problems. Learners with an external locus of control need help using CAI; perhaps by human intervention during CAI or by having better motivators built into the software. A more general solution to the problem of externals might be to assist them in developing systems of internal reward for learning.

The findings of this study support the notion that the tutorial mode of CAI should be used in teaching for basic concept understanding as measured on an achievement test. The simulation mode of CAI can be used to teach the applications of concepts. Measurement of the learning that occurs from each mode of CAI should be based on an appropriate assessment instrument. Applications tests should be used to evaluate learning from a simul ion, and achievement tests should be used to evaluate learning from a tutorial.

The finding that discrimination skill interacts with mode of CAI should alert CAI researchers to include individual learning differences in their assessments of CAI effectiveness and studies comparing CAI with other modes of instruction. Although some of the studies cited above reflect this concern, most studies included in the meta-analyses (Kulik et al., 1983; Wise, 1987) of CAI research did not.

## Recommendations for Future Research

Instructional research comparing treatments is always difficult due to the lack of standardization of treatments. The results of this study lead to a question regarding the equality of the two treatments. Specifically, was the simulation as good a simulation as the tutorial was a good tutorial? This problem is similar to that faced by researchers comparing two instructional techniques delivered by different teachers. The disadvantage of CAI research is that it is not easy to find additional tutorials and simulations that can be paired for comparison studies. Criteria for evaluating the effectiveness of a simulation or a tutorial at delivering instruction are virtually nonexistent. Any research comparing different modes of CAI needs to first establish meaningful criteria for comparing these "apples to oranges." Until such criteria are established, doubts will be raised for research findings as to the comparable effectiveness of the programs.

This study found a clear interaction between the two modes of CAI studied here and discrimination skill. The Learning Styles Profile should be used by researchers to determine if this skill interacts with other instructional modes. For example, do high discriminators learn less from discovery-based learning than low discriminators? Is the effect reversed for didactic instruction?

The various individual learning differences examined in this study were viewed as unidimensional. However, one might posit the extremes of these scales as orthogonal. For example, one might look at an individual's learning strategy as being composed of both holist and serialist dimensions (as Pask (1976) must have done when he defined versatile learners as those who used both holist and serialist strategies when appropriate). If one looks at the construct as orthogonal, then how do we evaluate these various dimensions of individual learning differences and what consequences do these new dimensions have on our understanding of learning and instruction?

The individual differences literature suffers from a plethora of terms and constructs. Although there might be little correlation between field orientation, learning strategy, and discrimination skill, the use of terms like holist, global, and low discriminator indicates a disposition toward describing the same construct. Are these measures of individual differences really measuring something so complicated with so many subtle aspects that still more instruments are needed to grasp the nature of learning, or are they all measuring a single simple component of learning? The answer to this question is at the heart of understanding how individual differences interact with instructional methodologies.

Finally, there is a clear need for a coherent testable theory of instruction that accounts for what we do know about instruction. The findings of instructional researchers seem to float about in a

References

Baird, W. E., & Koballa, T. R. (1986). Changes in preservice elementary teachers' hypothesizing skills and selected attitudes following group and individual study with computer-presented text or computer simulation. Auburn, AL: Auburn University. (ERIC Document Reproduction Service No. ED 266 946)

Bell, M. E. (1985, March). The role of instructionaltheories in the evaluation of microcomputer courseware. Educational Technology, 25, 36-40.

Coburn, P., Kelman, P., Roberts, N., Snyder, T., Watt, D., & Weiner, C. (1982). Practical guide to computers in education. Reading, MA: Addison-Wesley.

Cronbach, L. J., & Snow, R. E. (1977). Aptitudes and instructional methods. New York: Irvington.

Dahl, R. D. (1985). Interaction of field dependence independence with computer assisted instruction structure in an orthographic projection lesson. Dissertation Abstracts International, 45, 2012A.

Doerr, C. (1979). Microcomputers and the 3R's. Rochelle Park, NJ: Hayden Book Company.

Farkes, W. J. (1985) Affective feedback combined with two concept acquisition strategies in a computer-based instructional lesson. Dissertation Abstracts International, 46, 1177A.

Ford, N. (1985). Learning styles and strategies of postgraduate students. British Journal of Educational Technology, 16, 65-77.

Gagne, R. M., & Briggs, L. J. (1974). Principles of instructional design. New York: Holt, Rinehart, & Winston.

Gagne, R. M., Wager, W., & Rojas, A. (1981). Planning and authoring computer assisted instruction lessons. Educational Technology, 21, 17-26.

Gardner, R. W., & Moriarty, A. (1968). Personality development at preadolescence. Seattle, WA: University of Washington Press.

Heinze-Fry, J. A., Crovello, T. J., & Novak, J. D. (1984). Integration of Ausubelian learning theory and educational computing. American Biology Teacher, 46, 152-156.

Keefe, J. W., & Monk, J. S. (1986). Learning style profile examiner's manual. Reston, VA: NASSP.

Kulik, J.A., Bangert, R. L., & Williams, G. W. (1983). Effects of computer-based teaching on secondary school students. Journal of Educational Psychology, 75, 19-26.

McLaughlin, B. (1983). An experimental comparison of discovery and didactic strategies in the learning of computer programming computerized instructional -- Abstract. ACM Sigcue Bulletin, 17(3): 11.

Oltman, P. K., Raskin, E., & Witkin, H. A. (1971). Group Embedded Figures Test. Palo Alto, CA: Consulting Psychologists Press.

Pask, G. (1976). Styles and strategies of learning. British Journal of Educational Psychology, 46, 128-148.

Pask, G., & Scott, B. C. E. (1972). Learning strategies and individual competence. International Journal of Man-Machine Studies, 4, 217-253.

Post, P. E. (1985). The effect of students' field independence/field dependence on computer assisted instruction achievement. Dissertation Abstracts International, 45, 2013A-2014A.

Rotter, J. (1966). Generalized expectancies for internal versus external control of reinforcement. Psychological Monographs, 80 (1. Whole No. 609).

Rowland, P. & Stuessy, C. L. (1987, April). Effects of modes of computer-assisted instruction on conceptual understanding and achievement of college students exhibiting individual differences in learning: A pilot study. Paper presented at the meeting of the National Association for Research in Science Teaching, Washington, DC.

Rowland, P. & Stuessy, C. L. (in press). Matching mode of CAI to cognitive style: An exploratory study. Journal of Computers in Mathematics and Science Teaching.

Shaw, E. L., & Okey, J. R. (1985). Effects of microcomputer simulations on achievement and attitudes of middle school students. Hammond, LA: Southeastern Louisiana University. (ERIC Document Reproduction Service No. ED 255 389)

Stuessy, C. S. L. (1984). Correlates of scientific reasoning in adolescents: Experience, locus of control, age, field dependence-independence, rigididty/flexibility, IQ, and gender. Columbus, OH: The Ohio State University. (ERIC Document Reproduction Service No. ED 244 834)

Wesley, B. E. (1984). The effects of computer-assisted instruction and locus of control upon preservice elementary teachers' acquisition of computer literacy and the integrated process skills. Dissertation Abstracts International, 44, 3652A.

Wise, K. (1987, April). A synthesis of research on the effects of teaching science with microcomputers. Paper presented at the meeting of the National Association for Research in Science Teaching, Washington, DC.

TABLE 2

Pearson Correlation Coefficients Among Instruments Used in This Study

| | DISK | FDI | LOC | SERHOL | HEAT | HEAA | MODE |
|---|---|---|---|---|---|---|---|
| DISK | 1.00 | | | | | | |
| FDI | .10 | 1.00 | | | | | |
| LOC | .00 | -.34*** | 1.00 | | | | |
| SERHOL | -.05 | .10 | .09 | 1.00 | | | |
| HEAT | .01 | .15 | -.32** | .04 | 1.00 | | |
| HEAA | -.19* | .14 | -.36*** | .21* | .36** | 1.00 | |
| MODE | .06 | -.04 | -.07 | .01 | -.51*** | -.01 | 1.00 |

* $p < .05$

** $p < .01$

*** $p < .001$

TABLE 4

Analysis of Variance of the Regression of Mode of CAI, Discrimination Skill (DISK) and Their Interaction (DISK*MODE) on Home Energy Achievement Test and Home Energy Applications Assessment

| Source | DF | SS | *F* | *p* | Model $R^2$ |
|---|---|---|---|---|---|
| Dependent Variable = Home Energy Achievement Test | | | | | |
| MODE | 1 | 149.23 | 35.49 | .0001* | .32 |
| DISK | 1 | 2.09 | 0.50 | .4830 | |
| DISK*MODE | 1 | 33.67 | 8.01 | .0057* | |
| Dependent Variable = Home Energy Applications Assessment | | | | | |
| MODE | 1 | 0.04 | 0.01 | .9157 | .13 |
| DISK | 1 | 16.94 | 4.25 | .0421* | |
| DISK*MODE | 1 | 36.85 | 9.24 | .0031* | |

* $p < .05$

TABLE 4

Analysis of Variance of the Regression of Mode of CAI, Discrimination Skill (DISK) and Their Interaction (DISK*MODE) on Home Energy Achievement Test and Home Energy Applications Assessment

| Source | DF | SS | $F$ | $p$ | Model $R^2$ |
|---|---|---|---|---|---|
| Dependent Variable = Home Energy Achievement Test | | | | | |
| MODE | 1 | 149.23 | 35.49 | .0001* | .32 |
| DISK | 1 | 2.09 | 0.50 | .4830 | |
| DISK*MODE | 1 | 33.67 | 8.01 | .0057* | |
| Dependent Variable = Home Energy Applications Assessment | | | | | |
| MODE | 1 | 0.04 | 0.01 | .9157 | .13 |
| DISK | 1 | 16.94 | 4.25 | .0421* | |
| DISK*MODE | 1 | 36.85 | 9.24 | .0031* | |

* $p < .05$

TABLE 5

Analysis of Variance of the Regression of Mode of CAI, Locus of Control (LOC) and Their Interaction (LOC*MODE) on Home Energy Achievement Test and Home Energy Applications Assessment

| Source | DF | SS | *F* | *p* | Model $R^2$ |
|---|---|---|---|---|---|
| Dependent Variable = Home Energy Achievement Test | | | | | |
| MODE | 1 | 149.23 | 40.99 | .0001* | .41 |
| LOC | 1 | 75.19 | 20.65 | .0001* | |
| LOC*MODE | 1 | 13.01 | 3.58 | .0617 | |
| Dependent Variable = Home Energy Applications Assessment | | | | | |
| MODE | 1 | 0.04 | 0.01 | .9154 | .13 |
| LOC | 1 | 56.26 | 14.21 | .0003* | |
| LOC*MODE | 1 | 0.07 | 0.02 | .8897 | |

* $p < .05$

TABLE 6

Analysis of Variance of the Regression of Mode of CAI, Field Orientation (FDI) and Their Interaction (FDI*MODE) on Home Energy Achievement Test and Home Energy Applications Assessment

| Source | DF | SS | *F* | *p* | Model $R^2$ |
|---|---|---|---|---|---|
| Dependent Variable = Home Energy Achievement Test | | | | | |
| MODE | 1 | 149.23 | 34.31 | .0001* | .30 |
| FDI | 1 | 10.07 | 2.32 | .1314 | |
| FDI*MODE | 1 | 12.16 | 2.801 | .0978 | |
| Dependent Variable = Home Energy Applications Assessment | | | | | |
| MODE | 1 | 0.04 | 0.01 | .9202 | .02 |
| FDI | 1 | 9.04 | 2.03 | .1547 | |
| FDI*MODE | 1 | 1.68 | 0.38 | .5401 | |

* $p < .05$

TABLE 7

Analysis of Variance of the Regression of Mode of CAI, Learning Strategy (SERHOL) and Their Interaction (SERHOL*MODE) on Home Energy Achievement Test and Home Energy Applications Assessment

| Source | DF | SS | *F* | *p* | Model $R^2$ |
|---|---|---|---|---|---|
| Dependent Variable = Home Energy Achievement Test | | | | | |
| MODE | 1 | 149.23 | 32.57 | .0001* | .26 |
| SERHOL | 1 | 0.50 | 0.11 | .7431 | |
| SERHOL*MODE | 1 | 0.15 | 0.03 | .8588 | |
| Dependent Variable = Home Energy Applications Assessment | | | | | |
| MODE | 1 | 0.04 | 0.01 | .9190 | .05 |
| SERHOL | 1 | 20.01 | 4.63 | .0340* | |
| SERHOL*MODE | 1 | 2.57 | 0.60 | .4424 | |

* $p < .05$

TABLE 8.

Summary of Significant ($p < .05$) Main Effects (M) and Interactions With Mode of CAI (I) of Individual Learning Difference Variables on Concept Web (CW), Home Energy Achievement Test (HEAT), and Home Energy Applications Assessment (HEAA)

| Dependent Variables | Individual Learning Differences Variables | | | |
|---|---|---|---|---|
| | DISK | FDI | LOC | SERHOL |
| HEAT | I | - | M | - |
| HEAA | M I | - | M | M |

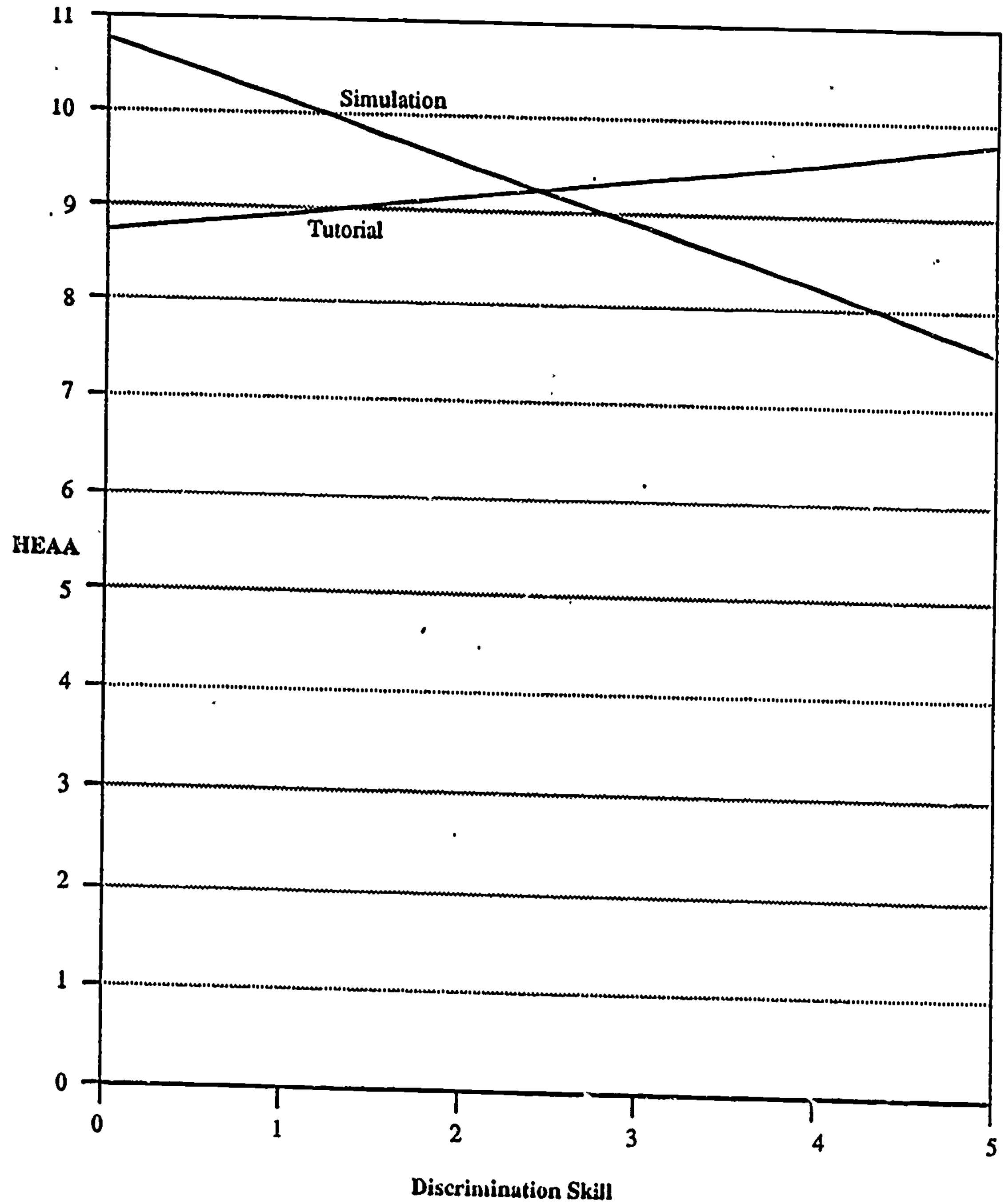


Figure 2. Predicted values of Home Energy Applications Assessment (HEAA) for tutorial users and simulation users by discrimination skills.