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ABSTRACT

This report presents the results of a study conducted to determine if the use of a microcomputer increases the problem solving ability of junior high school students. Two seventh grade classes from similar schools in the state of Virginia were selected for the study. The first group was exposed to introductory computer literacy skills and simple computer programming exercises for an entire year in a microcomputer laboratory, while the second group was not given computer instruction. The results indicate that the students exposed to computers show increased problem solving ability and that there are some differences in problem solving skills between boys and girls exposed to the computer. It is concluded that the computer is a useful tool for increasing problem solving skills and recommendations are made for curriculum changes and additions, including specific microcomputer software packages and computer activities that could further increase problem solving skills enhanced by the use of the computer. (Author/JB)

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The Effect of the Computer on Problem Solving Skills

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Abstract

This report presents the results of a study conducted to determine if the use of the microcomputer increases the problem solving ability of junior high school students. Two seventh grade classes from similar schools in the the state of Virginia in the United States were selected for the study. The first group was exposed to introductory computer literacy skills and simple computer programming exercises for an entire year in a microcomputer laboratory. The second group did not have a computer laboratory in the school. The results indicate that the students exposed to computers show increased problem solving ability and that there are some differences in problem solving skills between boys and girls exposed to the computer. The study concludes that the computer is a useful tool for increasing problem solving skills. Recommendations for curriculum changes and additions are made including specific microcomputer software packages and computer activities that could further increase problem solving skills enhanced by the use of the computer.

Introduction

"Children learn by doing and by thinking about what they do" (Papert, 1980, p. 161). This process of doing and thinking should ultimately provide children with the ability to solve problems. The introduction of the microcomputer into the learning process enhances the "doing" area of learning. It gives children the "power" to view and solve exciting problems. The skills used to solve problems are perhaps enhanced by the use of the computer. Students that are exposed to problem solving on the computer appear to be able to solve more difficult problems. They are able to apply problem solving algorithms that in the formal rather than experimental setting are lost to the learner.

The assessment of the impact of microcomputer use on the problem solving abilities of students has diverse benefits. Educational decision makers can make use of the data for substantiating the need for computers in the school. Curriculum designers could redesign portions of courses that teach problem solving and include a greater emphasis on computer learning. The classroom teacher will hopefully be more inclined to use the computer for project design, creation and implementation. In general, the educational community certainly realizes and enthusiastically embraces the need for the computer in the classroom because of its inevitable impact on society. However, if this report and future research can give some evidence to the increased problem solving ability that students gain from "doing" then the issues concerning the microcomputer in the classroom will perhaps have a central focal point. This report examines the impact of the computer on problem solving skills. The basic research presented was gathered from a small study that was designed to form a preliminary database for answering two important questions: First, "does the use of the microcomputer for learning increase problem solving ability?" Second, "is there any difference in the increase of problem solving skills between boys and girls?"

Background for Study

The emphasis of the research concerning the effect of classroom computer use on student performance has focused on comparing CAI (Computer-Assisted Instruction) to traditional instruction; the effects of computer programming by students on problem solving skills; and the opportunities for boys and girls exposure to computers. The major emphasis of research concerning general computer use has investigated the effect of CAI use on achievement when compared to traditional instruction (see for review Dence, 1980; Edwards, Norton, Weiss and Dusseldorp, 1975; Forman, 1982; Jamison, Suppes and Wells, 1974; and Kulik, Kulik and Cohen, 1981). Research that has investigated the effect of CAI and traditional instruction has generally shown that the combination of CAI and traditional instruction is the most effective and requires less instructional time than traditional instruction.

The reviewers of the CAI vs traditional instruction studies generally support the effectiveness of classroom computer use. Edwards, et al. (1975) concluded, as a result of their study in elementary schools, that traditional instruction supplemented by computer based instruction was more effective than traditional instruction alone. Jamison's et al. (1974) survey of the effect of CAI studies found that disadvantaged elementary school students appeared to show the most achievement gain when using CAI. These findings indicate that using CAI in conjunction with regular classroom instruction improves achievement, that students take less time to learn the material and students that are less academically prepared and from lower socioeconomic backgrounds appear to benefit more from computer use.

Dence (1980) and Kulik's et al. (1981) research studied the effect of computer use on student achievement with very similar results. Dence (1980) reported that CAI students that receive CAI and traditional instruction obtain higher scores than those students who receive only CAI or only traditional instruction. Dence (1980) also reported that CAI students appear to have a greater retention of material than students that were taught only by the traditional method. The research shows that regardless of the age of the student or type of hardware used by the student, achievement scores improve. Further, it seems that students who have prior experience with the computer or the subject tend to benefit even more from computer use.

The general conclusion drawn from the literature related to the issue of CAI vs traditional instruction is that CAI, when used as a supplement to traditional instruction, does produce greater achievement. Further, there appear to be factors other than the delivery method that influence achievement when CAI is used in schools. For example, the socioeconomic factor introduced by Jamison et al. (1974); the prior familiarity factor introduced by Dence (1980); and the ability factor, addressed by Jamison et al. (1974), seem to influence the amount of achievement gain and instruction time.

Investigations of the effects of computer programming by students on problem solving skills (Johnson, 1966; Harding, 1974; Milner, 1973; Ronan, 1971; Wilkinson, 1973; and Holoien, 1971) have also been conducted. Research has shown that students learn the content better when they write and run their computer programs. Foster (1973), for example, investigated how students' use of computers and flow charts effect their problem solving ability. Sixty-eight eighth graders were placed in four treatment conditions: (1) use neither computer nor flow chart; (2) use flow charts only; (3) use computers only and (4) use computers and flow charts, (Foster, 1973). Over a period of twelve weeks each student was provided with 24 tasks that required both computer and non-computer solutions. Foster found that the third condition (i.e. only used computer) had significant mean differences on processing hypothesis, identifying a pattern, and selecting relevant data. The data also showed that group 2 and 4 performed better than the groups that used neither the computer nor flow chart. Milner (1973) and Ronan's (1971) findings were very similar to Foster's (1973). That is, students that were taught programming and given problem solving tasks to perform showed greater achievement gains than those students that did not use the computer.

There is also a growing body of anecdotal evidence concerning opportunities for exposure to computers (Hess and Miura, 1983; and Walker, 1983). The anecdotal data addressing the issues of women and minorities exposure to computers seem to indicate that unless the trend changes women and minorities may become "...the 'technopeasants' of the future" (Walker, 1983, p. 6). For example, Hess and Miura (1983) found that there was a definite sex and class range for students enrolled in summer computer camps, i.e. mostly Caucasian upper to middle class male. Tinker (1983) reports that most of the purchasers and users of computer games are Caucasian educated men. Van Huys (1983) contends that it is more likely that boys will be encouraged and supported in their quest for computer training than girls. Thus, it appears that women and minorities are less likely to participate in computer camps; progamming and computer literacy classes, and computer game playing. Based on this literature it seems likely that girls in this study will exhibit less exposure to computers and a smaller if any increase in problem solving scores than boys.

Description of Study

The research comparing CAI to traditional instruction and the research investigating the effect of computer programming on students' problem solving behaviors indicates that general computer use enhances students' achievement and problem solving performance. Further, research indicates that boys have greater exposure to computers than girls, thus there may also be a greater increase in problem solving scores of boys than girls.

The present study while continuing in the same tradition as those previously cited, differs on several specific features. First, the treatment consisted of exposing only one group of students to the computer in a computer class. All students at the treatment school were required to participate in the computer portion of the course, however, the students were not trained in a specific computer skill nor were they given specific CAI material to use. They were given a variety of computer experiences including games, programming, CAI and simulations. The control group did not use computers in their math class.

The second unique feature of this study is that data were obtained from already existing school records of eighth grade students in both schools. Problem solving behaviors were assessed by students' performance on the problem solving subtest of the SRA Achievement Series Test. Finally, prior familiarity was manipulated by assessing students' general use of computer through their ratings on the Exposure to Computers Index based on Anderson et al. (1981). It should be noted that for the pruposes of this study, general computer exposure was defined as using CAI, gaming and simulation, computer programming and experience with arcade games.

The Exposure to Computers Index was used for the reasons of ecological validity; it was reasoned that while general computer use has been used to establish the power of a variable, validation to a natural setting with students of similar socioeconomic status and intellectual ranking, the Exposure to Computers Index would strengthen the conclusion of the difference in performance being due to general computer use in the classroom.

Thus, the predictions based on the research were: (1) students that are exposed to computers in an organized class, regardless of their prior exposure to computers, will show significantly higher problem solving scores on the problem solving measure; (2) students that have had little or no prior exposure to computers and are exposed to computers in the classroom will show significantly higher problem solving scores on the problem solving measure than no prior exposure students that did not use the computers; and (3) boys with or without prior exposure that are exposed to the classroom computer use will show significantly higher problem solving scores on the problem solving measure as compared to the girls.

Procedure

The experiment was conducted during the 1981-82 school year. The students were in the seventh grade. The experimental school was chosen by the fact that it was the only junior high school in the city where all students within a grade would use computers. The control school was chosen because it was more similar to the experimental school than any other junior high school in the city.

Standardized test scores and other relevant data were gathered from school records by the experimenters and recorded. They were assisted by two college student assistants. Data include scores for reading, math, problem solving and EAS - Educational Ability Series Tests and socioeconomic status.

The curriculum at Woodrow Wilson did not, at the time of the study, include instruction using computers. Students at Breckinridge were scheduled into the microcomputer classes during the 1981-82 school year.

Selection of Students

Students selected for this study came from two American seventh grade classes in Roanoke, Virginia, Breckinridge and Woodrow Wilson. These schools have similar socioeconomic profiles and are two of the six junior high schools.

The population at both schools can be described as middle-income but with some lower-income and higher-income families. Single family homes predominate the neighborhoods from which these schools draw students and both school populations include students who live in federally-funded housing projects.

The city's school population is 20% black and almost 80% white. At Breckinridge approximately 23% of the sudents were black and at Woodrow Wilson approximatley 26% of the students were black. Less than 1% of the students from either school belong to other ethnic or racial groups.

Both schools consider their student population very stable; with transient students not a problem. The ability levels and achievement levels of the total student population within the two schools are similar.

Selection of Tests

Several testing instruments were used in this study. The problem solving ability was assessed via the problem solving subtests of the mathematics portion of the SRA Achievement Series, (SRA, 1980). Sixth grade scores were used as a pre-test; seventh grade scores were used as a post-test. To determine the level of prior exposure to computer use, questions were formulated based on the Anderson, et al. (1981) study.

The SRA Achievement Series was used for several reasons. It has previously established levels of reliability and validity. Since students take these tests every spring as part of the school's regular testing program, they cost students no out-of-class time. They provided pre-test information which could not have been obtained otherwise. The math portion of the SRA Achievement Series included a subset addressing the areas of problem solving.

The Exposure to Computers Index (Anderson, et al., 1981) was used as the measure of students previous exposure to computers. It was taken from a study of affective and cognitive effects of microcomputer based instruction.

Method of Testing

The SRA tests were administered by homeroom teachers within each school. Students took these tests in the Spring of 1981 and 1982 as part of the regular school program. Teachers giving these tests received standardized instructions for administering them.

The Exposure to Computers Index (Anderson, et al., 1981) was duplicated and distributed to all students in the two groups during homeroom at the beginning of grade seven. Students were instructed to answer "yes" to question 2 only if they had a course other than the present computer course in grade 7. Directions for answering the questions were read by the teacher. The students responded on the sheet and then turned in the form. The questions required only a "yes" or "no" answer.

The four questions asked were:

1. I have used computers in school

2. I have taken a course about computers

3. I have written computer programs

4. I have played computer games in an arcade.

If 3 out of 4 questions were answered "yes", the student was classified as a high exposure subject.

Results

The factors of 2(school) X 2(sex) X 2(exposure) were investigated relative to mean gains in problem solving scores (GainPS) and pretest scores on the sixth grade Educational Abilities Problem Solving Portion of the test (EPSPSSIX). The means, standard deviations, and number in each cell are shown in Tables 1 and 2. Table 3 reports the precentage and number for the Exposure Index.

Rather than adapt the conventional alpha level of .05 a decision was made to relax alpha to .10 due to the modest treatment effects that were anticipated. This shift from .05 to .10 will double the probability of a Type I Error (i.e. accepting a null that is not true) but will increase the power of the tests to be conducted and thereby increase the probability of detecting modest treatment effect.

Analysis of variance of the Educational Abilities Problem Solving Sixth Grade (EASPSSIX) test scores showed significant mean differences (Table 1), between the students at Breckinridge and the students at Woodrow Wilson, $F(1,7532.23)=498.59$ $p=0.000$. It appears that the students at Woodrow Wilson, the control school, started out with higher problem solving scores than students at Breckinridge. Further, in both instances boys had significantly higher, $F(1,7532.23)=199.99$ $p < .02$, problem solving scores than girls at either school. (Table 2).

Two analyses were conducted on the simple GainPS. Simple gain scores were used because the scores of students from both ends of the ability spectrum (i.e. high and low ability) were included in the study. This decision was based on the assumption that the scores regress toward the mean which balances the distribution. The first analysis, analysis of variance, showed that boys at Breckinridge had significantly, $F(1,173)=3.387$ $p < .07$, greater problem solving gain scores than girls at either school or boys at Woodrow Wilson (Table 1), when exposure level was a factor in the analysis. The small number in the high exposure groups at Woodrow Wilson is anomaly and has probably skewed the data. However, the means, standard deviations, and numbers reported in Table 2 represent a better picture of the problem solving scores because exposure was not a factor. The findings reported in Table 2 concur with those in Table 1. That is, boys at Breckinridge had significantly higher problem solving gains than girls at either school or boys at Woodrow Wilson.

The means in Table 2 also show that girls at both schools did not differ significantly in their mean gain problem solving score. The second analysis of the gain problem solving was an analysis of covariance. Educational Abilities Problem Solving Sixth Grade score was the covariant in this analysis. The analysis showed a two way interaction between sex and school. As reported earlier, the boys at Breckinridge in this analysis also had significantly, $F(1,4121.64)=58.705$ $p < .0888$, greater problem solving gains than girls at both schools and boys at Woodrow Wilson.

Data shown in the Exposure to Computers Index Table (Table 3) concurs with the literature, i.e. boys have greater exposure to computers than girls. The data shows that a larger percentage of boys have taken courses in computers and have written programs. Even though the percentage of boys (98%) that have played computer arcade games is greater than girls (94%), the margin of difference is small.

Table 1

The mean, standard deviation (SD), and number (N) in each condition, by school, sex, and exposure relative to gain problem solving scores (GainPS); pretest or sixth grade Educational Abilities Scores, (EASPSSIX); post test on seventh grade Educational Abilities Score (EASPSSEV).

Group EAS6	Pretest (EASPSSIX)			Post Test (EASPSSEV)			Problem Solving Gain (GainPS)		
	N	SD	Mean	N	SD	Mean	N	SD	Mean
				Breckinridge (a)					
<u>Girls</u>									
High Exposure	18	7.77	16.72	18	6.62	19.72	17	4.73	3.18
Low Exposure	40	5.29	15.95	40	5.80	17.28	33	4.05	1.61
<u>Boys</u>									
High Exposure	20	6.70	20.05	20	7.28	21.50	19	3.63	1.53
Low Exposure	22	5.02	15.45	22	5.58	18.82	21	4.45	3.52
				Woodrow Wilson (b)					
<u>Girls</u>									
High Exposure	2*	10.61	19.50	3	8.66	20.00	2	0.00	-2.00
Low Exposure	59	5.61	18.83	58	5.88	20.90	48	3.81	2.44
<u>Boys</u>									
High Exposure	6*	1.79	27.00	6	1.51	26.67	4	1.73	-0.50
Low Exposure	43	6.23	20.47	42	5.83	21.52	37	3.70	1.14

(a) Breckinridge is the experimental school
(b) Woodrow Wilson is the control school

* Indicates small number in group

Table 2
The mean, standard deviation (SD), and number (N) by school and sex relative to Gain Problem Solving Scores and Educational Abilities Problem Solving Scores for sixth grade

Group	Educational Ablilites Problem Solving Sixth Grade			Problem Solving Gain		
	N	SD	Mean	N	SD	Mean
			Breckinridge			
Girls	58	6.103	16.19	58	4.07	1.845
Boys	42	6.25	17.64	42	4.09	2.45
			Woodrow Wilson			
Girls	62	5.68	18.85	62	5.15	1.97
Boys	49	6.24	21.29	49	4.33	.486

Table 3
Exposure to Computer Index Table

Question	Girls	N	Boys	N
1. Number of students that used computers in school	50%	58	50%	42
2. Number of students having taken a computer course	11%	13	23%	19
3. Number of students having written computer programs	14%	16	24%	20
4. Number of students having played computer arcade games	94%	110	98%	82

Note: Adapted from Anderson, R.E., et.al.

Discussion

The results present several interesting areas for discussion and further study. The three major findings are that: 1) boys exposed to the computer had increased problem solving gain scores; 2) a greater number of experimental boys had higher prior exposure to the computer;

and 3) the experimental group had pretest problem solving scores which were significantly lower than the control group.

The three results indicate that use of computers can increase problem solving skills for boys. In addition, it seems that if students are previously exposed to computers they have an even greater chance of developing better problem solving skills. The exposure to computer index indicated that boys had greater exposure to computers than girls via computer courses, computer programming and arcade games. Therefore, girls should be encouraged to participate in these types of activities for increased problem solving skills. Teachers and guidance counselors need to be educated about the inherent benefits to all students that use computers.

The exposure to computer index tables further show that a larger percentage of boys had taken a computer course and had written computer programs. This may have attributed to the greater problem solving gains for boys. The exposure to computer index tends to support this reasoning. Thus, educators should encourage females to enroll in computer classes and to write computer programs even though they show some degree of computer anxiety.

Recommendations

This study although small in subjects provides a basis for discussions concerning the relationship of computer usage to problem solving. In reviewing the issues, it is neces ry to develop a definition of problem solving. This definition is not only important to computer educators but to all educators.

A brief working definition of problem solving has four parts:

1. State the problem
2. Identify the initial state (known and unknown values)
3. Identify the final state (how will you know when it is reached or if it cannot be solved with the known values)
4. Plan the action (algorithm) necessary to get from the initial state to the final state.

This simple definition encompasses both the philosophy and the activity of problem solving (Moursund, 1985). It provides some guidelines for software designers and classroom teachers.

Software designers and developers must be sure that the software provides "labels" of the problem solving skills that are used in the program. The continuous highlighting of the skills will provide the student with a problem solving algorithm that can be transferred to an unrelated environment. Using a well designed piece of software such as LOGO or Rocky's Boots (Learning Company) does not insure that the skills learned while solving one problem will be applied to new problems. Students need to be taught that problem solving is also a skill that can be learned by study and practice.

Classroom teachers need to select software that clearly teaches problem solving skills with the other skills presented in the program. Teachers should be aware of the skills that students need to master to become effective problem solvers. A problem solving matrix developed under the direction of Donna Stanger of the Rochester New York School District (Sunburst, 1985) suggests a set of problem solving skills that can be taught and/or enhanced with microcomputer software. Table 4 lists these skills.

Table 4
Problem Solving Skills

Memory	Cognitive Skills Discrimination, Attributes and Rules	Cognitve Control Strategies	Creativity
Mnemonic Systems	Higher Order Rules	Simultaneous Scanning	Fluency
Visual Association	Rules	Selecting Appropriate Notation	Flexibility
Whole to Part	Defined Concepts	Identifying Multiple Solutions	Originiality
Self Testing	Concrete Concepts	Examining Assumptions	Elaboration
Creating a Context	Discrimination	Working Backward	
Personalization		Using a Model	
Regrouping		Focus Gambling	
Auditory Aids		Conservative Focusing	
Number of items to Remember		Estimating, Predicting, Projecting	
Sequence		Scanning for Clues, Hints	
		Restating the Problem	
		Analyzing	
		Making Organized Lists	
		Looking for a Pattern or Sequence	
		Brainstorming	
		Openness to Insight, Flexibility	
		Successive Scanning	
		Retrieval Strategies	
		Information Gathering	
		Problem Finding	

Some of these skills are taught in a variety of microcomputer programs now on the market. A list of some of the current programs that attempt to deal with problem solving is at the end of this paper.

Finally, school administrators (i.e. counselors, curriculum coordinators and superintendents of instruction) must also attempt to insure that problem solving skills are taught. These skills can be studied through a variety of methods. However, the research presented in this paper tends to support the use of the computer for enhancing problem solving skills. Units designed to teach problem solving should outline methods for solving a variety of problems and then correlate this information with the use of appropriately selected software. After using the software, the problem solving learnings should be reviewed and clearly stated. If needed, supplementary material on problem solving should be developed for use in conjunction with selected software. It is essential for administrators to delineate problems on the basis of the role computers can play in their solution.

Conclusion

The use of computers in education will continue to grow at an even more rapid rate than today. Educators need to know that the computer is more than a "fun" way to learn. If computer use does increase problem solving ability then the designers of curriculae should incorporate this factor into learning programs.

Curriculum will need to be designed with an increased emphasis on higher-level cognitive processes. The increased use of the computer as an aid to problem solving will broaden the scope of problems that students can attempt to solve (Moursund, 1985). It will be up to the administrators of our educational system to help implement this change.

Therefore, if the computer can be used and one of the inherent benefits, whether formally identified or imbedded in the "nature of the beast", is an increased problem solving ability, for both boys and girls, then learning with micros is certainly ideal.

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Problem Solving Software

Program	Company
The Pond The Incredible Laboratory The Factory Odd One Out The King's Rule Sem Calc Code Quest Teasers By Tobbs Memory, The First Step Puzzle Tanks M-ss-ing L-inks	SUNBURST Communications Room BQ 141 39 Washington Avenue Pleasantville, NY 10570
Gertrude's Secrets Gertrude's Puzzles Rocky's Boots Moptown Parade Moptown Hotel Trains	The Learning Company 545 Middlefields Suite 170 Menlo Park, CA 94025
In Search of the Most Amazing Things Snooper Troops #1 and #2	Spinnaker 215 First Street Cambridge, MA 02142
Murder By The Dozen The Voyage of the Mimi	Holt, Rhinehart & Winston CBS Educational and Professional Publishing 383 Madison Avenue New York, NY 10017