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ABSTRACT

The effect of computer-assisted instruction on spatial problem solving skills was examined in this study. Subjects were fifth grade students from nine classes, who were divided into thr e treatment groups in a nonrandom fashion: (1) computer-assisted group, which used computer software designed to help students improve spatial problem solving skills for one hour per week; (2) worksheet group, which used worksheets and seatwork exercises designed to enhance spatial problem solving skills for one hour per week; and (3) control group, which had no special instruction in problem solving. Students were pre- and posttested with the New Jersey Test of Reasoning Skills, the Sequencing and Analogies subtests of the Test of Cognitive Skills, and a seven-item noncommercial spatial test. A Cognitive Skills Index (IQ score) for each student obtained in fourth grade was also used in the analysis. Results of multivariate tests indicated that the effects of group and sex were not significant, but the effect of schools was statistically significant. However, no significant differences were found between the three treatment groups, although all groups showed a gain from pretest to posttest. It is suggested that the use of computer-assisted instruction is less effective as a stand alone teaching method than it would be as a supplement to teacher instruction. The text is supplemented by four figures, and the materials provided to the teachers whose classes participated in the study are appended. (4 references) (EW)

EFFECT OF THE COMPUTER ON PROBLEM-SOLVING

Hinsdale District 181

Submitted to:

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Mrs. Mary Ellyn Madden

Submitted by:

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Research Coordinator

May, 1984

TABLE OF CONTENTS

INTRODUCTION

According to current research, daily access to computer-assisted instruction for periods of ten to twenty minutes can increase student performance on tests. This finding has been replicated in several studies and reported in a recent review article (Kulik et al., 1983). The Kulik research synthesis shows a positive effect on student achievement for computer-assisted instruction of various types: drill and practice, tutorial, simulation (largest effect), computer-managed instruction, and programming to solve problems (smallest effect). They report previous research showing that the effect tends to be stronger for elementary than for secondary students, and stronger for tutorial than for drill and practice programs. The synthesis performed by Kulik et al. showed stronger effects for low and middle ability students and for studies of four weeks or less in duration.

Kulik et al. also reviewed studies of the effect of computer-assisted instruction on student attitudes, and found small but consistently positive effects.

Like an earlier Educational Testing Service study (Ragosta et al., 1982) the Kulik review focused on student achievement on examinations in traditional subject areas such as mathematics and language arts. However, in addition to helping students learn core subject material, computers are also credited with enhancing problem-solving skills. Though this notion appears self-evident to anyone who has worked with computers (specifically with children and computers), little empirical evidence is yet available.

Much of the research currently available in the area of problem solving has been done in relation to gifted education. However, a study of strategies of gifted children in solving the "Mastermind" problem (Ludlow and Woodrum, 1982) shows that average and gifted children used similar problem-solving strategies. They conclude, "Educators must develop curricula which include the acquisition, use, and refinement of higher level cognitive abilities (including problem-solving)...and design techniques and strategies for use by teachers in eliciting and improving these skills through a variety of media and content areas." (p. 103)

A great deal of the computer use in District 181 has been in that semi-defined area of problem-solving. Students receive instruction in the logic of computer programming, and use software designed to stimulate their thinking. Thus, the district setting is one which is amenable to the investigation of the effectiveness of the computer as an aid to learning problem-solving skills.

BACKGROUND

During the 1982-83 school year, a small-scale experimental study of using the computer to enhance problem-solving in mathematics was carried out in the district. A one-week unit on coordinate geometry was taught to fourth graders. A true experimental design was employed. According to Simpson (1983) "Schools were randomly selected to be in the experimental group in which students worked with Bumble Game software as part of their normal instruction in the math class coordinate geometry unit. In the control group schools, students received instruction in coordinate geometry as usual, with no auxiliary use of computer software." (p. 2)

Because the posttest scores for both groups were very high, there was little opportunity to detect effects of computer use on students' learning of coordinate geometry. The data analysis showed a borderline result: statistically non-significant when analyzed with all schools, significant when analyzed with Walker School data removed. Summarizing the findings, Simpson states:

> Students using the computers for the coordinate geometry unit performed slightly higher on the posttest than did control group students but the difference in scores was slight...The results of this experiment, then, are suggestive rather than definitive. (1983, p. 9)

One of the recommendations based upon the coordinate geometry/problem-solving experiment was to carry out another experimental study under different conditions. The conditions suggested were: 1) develop a definition of "problem-solving" and delineate skills and behaviors which would be evidence of problem-solving, 2) identify software which specifically addresses those skills and behaviors, 3) develop alternative measures of such behavior, and 4) use a longer experimental period. This recommendation was adopted by the district, and resulted in the experiment described in this report.

METHOD

The project commenced with work on the definition of problem-solving by a district committee. For the purpose of the study, "problem-solving" has been defined as skill in solving visual-spatial problems. The abilities to mentally manipulate shapes, to perceive relationships among two-dimensional figures, and solve spatial reasoning problems were included in the working definition of problem-solving. Since these skills are measured on most intelligence and aptitude tests, they are related to general intellectual performance rather than to particular subject area performance.

Nine fifth grade classes were assigned to one of three groups:

1. Computer-assisted group. Students used computer software designed to help students improve spatial problem-solving skills for one hour per week.

2. Worksheet group. Students used worksheets and seatwork exercises designed to enhance spatial problem-solving skills for one hour per week.

3. Control group. Students had no special instruction in problem-solving.

Assignment of classes to groups was nonrandom. Teachers volunteered to be in the computer group or the worksheet group, with the remaining classes serving as control. Three classes were in each group. These nine classes represented all fifth grade classes at six of the seven district schools. The Lane School was not included because of its different system of grade-level organization. Figure 1 presents the distribution of classes and students among the three groups.

FIGURE 1

Group	School	Teacher	Number of Students
Computer	Oak	De Bickero	25
	Walker	Otto	14
	Prospect	Tupy	17
Worksheet	Madison	Hummer	27
	Elm	Massura	32
	Monroe	Ranck	22
Control	Prospect	Gelwicks	17
	Oak	Webb	23
	Monroe	Boyleston	21
		TOTAL	198

Since time spent actively engaged in learning is an important variable in any study of achievement, it is a variable which must be held constant in all groups which are receiving a treatment. Thus, teachers of the computer and worksheet groups were asked to keep log sheets of the actual time spent by each individual (for computer group) or the entire class (for worksheet group) on the visual-spatial instruction. In preparation for the experiment, a meeting was held for all fifth grade teachers from the six schools involved. The project description and instructions for implementing the different treatments were distributed and discussed. The materials are reproduced in Appendix A

Teachers of the computer group were instructed that their students were "to work solely with the computer software." Thus little or no teacher instruction and use of supplementary worksheets occurred in these groups. The instruction was basically provided by the computer programs alone.

Teachers of the worksheet groups were given packets of worksheets numbered in the sequence in which they were to be used. They were to to plan lessons around these using the following steps: "1. Teacher explanation of main idea of the lesson, 2. Working through one or two examples with whole class, 3. Time for students to work individually on several examples OR group work."

Control group teachers were asked only to refrain from using the problem-solving software and the worksheets during the study.

All students were pre- and posttested with the following instruments: New Jersey Test of Reasoning Skills, Sequences and Analogies subtests of the Test of Cognitive Skills, and a seven-item spatial test (non-commercial). A Cognitive Skills Index (IQ score) for each student obtained in fourth grade was also used in the analysis.

Students were pretested during the week of December 12, 1983. Instruction commenced in the computer and worksheet groups the first week of January, 1984, and continued through the last week of February for a total of eight weeks. Posttesting occurred the week of March 5.

A debriefing meeting for fifth grade teachers was conducted by Ann Dana, District 181 Computer Consultant, in April following all posttesting, but preceding analysis and reporting. Teachers were invited to comment upon any aspect of the study and to ask questions. They were also assured that they would be informed of the results of the study when those were available.

DESCRIPTION OF MATERIALS AND TESTS

Software

Most students in the computer groups used four software packages at some time during the eight weeks of instruction. Two software packages were available for the first few weeks of January, "Flip Flop" and "The Factory," both produced by Sunburst.

According to the publisher's description, "Flip Flop" is designed for students in grades four through six. The purpose is to provide practice in visual discrimination through two "games." The first game requires identification of a figure which is the same as a given figure, but which may have been either rotated or flipped. The second game requires the student to manipulate a second figure until it appears in the same orientation as the given figure. Both games offer ten problems at each of four levels. Since the version of "Flip Flop" used was prepublication, a few bugs remained in the software and sometimes interfered with students' use of it.

"The Factory" is intended for use by students in grades four and up. According to Sunburst, "The program challenges students to create geometric 'products' on a simulated machine assembly line" whose machines they design. Students must use inductive thinking, visual discrimination, spatial perception, and logic to succeed in the tasks. Students are stimulated to use problem-solving strategies such as working backwards, analyzing a process, determining sequence, applying creativity, and seeking a more efficient solution. Students are introduced to "The Factory" by testing the effects of various machines. Then they build their own assembly line and watch the results. Finally they are challenged to build an assembly line which will duplicate a given product. This software package won the "Best Software of the Year 1983" award given by Learning magazine.

During the latter half of the instructional period, two additional software packages became available for use with students. These were "Fun House Maze" and "Jigsaw Jenerator." The former is another in the Sunburst series "Strategies in Problem Solving" designed for use in fourth grade and above. Students aim to discover the repeating pattern of turns which will lead them out of a three-dimensional maze. They can either guess the pattern itself, or apply it as they move through the maze to the exit. The patterns are randomly generated by the computer. The program's teaching objectives are "1. To provide practice in pattern recognition and identifying multiple solutions, 2. To build skills in the problem solving strategies."

"Jigsaw Jenerator" is produced by L & S Software of Chicago. Students are challenged to assemble puzzles of ten to forty-nine pieces on the screen. The pieces must be rotated and the positions matched carefully before correct placement will be accomplished. The player is offered options concerning the picture formed and the number of pieces in the puzzle.

Worksheets

Most of the worksheets used were gleaned by the research consultant from a Barron series book on preparing for tests of various kinds. The title of the section in which the pages were found was "Mechanical Aptitude and Spatial Relations Tests." The pages were intended to be used as practice for taking such tests.

The microcomputer consultant also located a set of worksheets called Figure Relations (B) in gifted education materials by Midwest Publications. These worksheets were provided to the teachers. Brief tips for use were included with the worksheets, as well as an indication of the sequence in which they were to be used. No answer keys or specific lesson plans were provided.

Tests

The New Jersey Test of Reasoning Skills is a fifty-item multiple-choice paper and pencil test of elementary reasoning and inquiry skills. It was developed by Dr. Virginia Shipman, Senior Research Psychologist with Educational Testing Service. The items on the test are designed to concentrate on logical reasoning, and therefore items drawing on other skills such as vocabulary and computation have been avoided. The reading level is reported as being between 4.5 and 5.0. The youngest level for recommended use is fifth grade. The reported reliability is .84 which is quite adequate for research use. Examples of skills tested are part-whole reasoning, discerning causal relationships, identifying good reasons, syllogistic reasoning, distinguishing differences of kind and degree, and detecting assumptions. The author states that the same form of the test may be used for both pre- and post-testing if both are done in the same year.

The Test of Cognitive Skills (TCS) is an ability test designed to assess a student's academic aptitude. It is published by CTB/McGraw Hill. Each level of the TCS includes four subtests: Sequences, Analogies, Memory, and Verbal Reasoning. Level 2, for grades three through five, was used in the problem-solving study, given as a pretest at the end of grade four and as a posttest immediately following the instruction. The Cognitive Skills Index (CSI) is an IQ-like score computed from a student's score on the four subtests and his/her chronological age. It is a normalized standard score with a mean of 100 and standard deviation of sixteen.

In addition to the CSI, scores on two of the subtests were used in the data analysis for the present study. The Sequences and Analogies subtests were chosen because they were most like the problem-solving instruction in that they are presented largely through figures rather than words. They do not, however, require mental manipulation of these figures in space, as will be seen in the descriptions below.

The Sequences subtest contains twenty items designed to measure the student's ability to recognize a pattern in a sequence of figures, and to extrapolate to a rule. Some of the patterns used are progressional sequences and combinations of parts to form a whole. Four items involve rotation or flipping as part of the sequence.

The Analogies subtest contains twenty items that measure the student's ability to recognize literal or symbolic relationships. These items reflect such "problem-solving" tasks as comparing, perceiving the function of an object, understanding degree or proportion, and recognizing a numerical, quantitative, or spatial relationship. Of the twenty items, three required the type of visual-spatial skills practiced by the students during instruction.

The seven-item spatial test was found in a Barron's series book on preparing for test-taking. The test is titled "Spatial Views Test I." Students are given separate top, side, and front views of an object, then asked to pick its three-dimensional representation.

DESIGN

A quasi-experimental design was chosen. This differs from a true experimental design in that selection and assignment of classes to treatments was not random. This design does however provide most of the same controls that an experimental design does, dependent on the extent to which the classes assigned to the various treatments are similar. In addition, a statistical adjustment for some of the pre-existing differences among classes can be made through use of covariates in the data analysis.

Factors such as instructional time, materials used, and time of year were controlled through the instructions to teachers. The factor of outside opportunities to learn, either prior to or during the experiment, was controlled by the selection of visual-spatial manipulations as the topic of study. This topic is not commonly taught in or out of school at the fifth grade level.

Multivariate analysis of covariance was used to analyze the data. "Multivariate" means that multiple dependent variables (posttests) may be considered simultaneously. "Covariance" means that posttest scores will be adjusted for the effects of other related variables in order to "equalize" the groups. The covariates employed in this analysis were IQ and pretest scores on the New Jersey test and the spatial test. The dependent variables were posttest scores on the New Jersey test, the spatial test, and the Sequences and Analogies subtests. The independent factors were treatment group, sex, and school. Sex and school were included as control factors since both are potential causes of variation in posttest scores. If they are controlled by being included in the design, their effects will not interfere with detection of variation in posttest scores caused by assignment to a treatment group, which is the primary factor of interest.

REPLICATION OF STUDY

Two maladies commonly affect educational research. The first is obtaining nonsignificant results due to not using a large enough sample size. The second is obtaining significant results, only to find that no one else can replicate them. In an effort to avoid both of these situations, District 181 secured the cooperation of another district in replicating the study described in this report. The Cupertino Union School District in California shares an active interest in the use of microcomputers in schools, yet represents a different setting in terms of both student population and program. A reciprocal agreement was devised according to which District 181 replicated a computer literacy study originally carried out in Cupertino, in exchange for their cooperation in replicating the problem-solving experiment.

Three fifth grade classes, each assigned to one of the groups described above, are involved in the Cupertino study. Their eight-week period of instruction occurred during the months of April and May, 1984. Students were given the same tests as the District #181 students, and used exactly the same software and worksheets.

When the results of the Cupertino study become available, they will be analyzed in combination with the District #181 results.

RESULTS

Time Logs

Teachers of the computer group were asked to keep records of time spent with the visual-spatial software for each individual student in the class. Two teachers handed in very complete logs for their classes.

The first log showed that for six of the eight weeks nearly every student (absent students excepted) spent three twenty-minute sessions at the computer with a partner. The other two weeks were disrupted by field trips, holidays, etc. and only two twenty-minute sessions were held. Records indicated that no one student missed more than three sessions due to absence.

The second complete log indicated that each student spent sixty minutes each week for eight weeks using the problem solving-software. Most of that time was spent in pairs at the computer, though some was spent in triples and some spent alone.

The third computer group teacher described for the class as a whole the procedures that were used. She stated that students in her room were on the computer in pairs for thirty minutes twice a week for the first four weeks, and in triples twice a week for thirty minutes for the last four weeks of the study. She did not indicate deviations from this for particular weeks or particular students.

One worksheet teacher indicated on her time log that she spent twenty minutes three times per week for for seven weeks of the study, with two twenty-minute sessions the eighth week. These were whole-class sessions. Absences of individual students were recorded; no one student missed more than three sessions. No make up lessons were given.

The second worksheet teacher indicated teaching sixty minutes total for each of six weeks, three times in two sessions of thirty minutes and three times in three sessions of twenty minutes. One of the other two weeks had seventy minutes and the other had forty minutes of instruction. No student missed more than three sessions, and lessons were generally not made up.

The third worksheet teacher indicated an irregular pattern of scheduling for lessons. Only seven weeks included instruction since the first week was devoted to "testing" and the week of February 13 missed due to Outdoor Education. The number of minutes per week ranged from forty-five to sixty-five and lengths of individual sessions ranged from ten to thirty-five minutes.

Monitoring Visits

Thirteen visits were made to computer group classrooms over the eight weeks of the instruction, and twelve visits to worksheet classrooms. Visits were made by the district microcomputer consultant, the IER research consultant, and a microcomputer consultant from IER. Most visits included observations of the students learning visual-spatial skills either on the computer or with worksheets. A few visits consisted only of conversations with the teacher regarding her implementation of the treatment and the students' reactions to it.

Students in the computer group were observed using Factory (four times), Flip Flop (one time), Fun House Maze (four times), and Jigsaw Jenerator (two times). In only one case did a session include a teacher giving instruction to a group about how to use a program; in all other visits the students were using the computer independently. No observation was made of records being kept of student performance on a program. Students working together in pairs or triples were generally observed to do so well, with all members of each group actively participating whether at the keyboard or not. In at least one class, students sitting near the computer, but not supposed to be working on it, also watched and gave suggestions to the student on the computer.

Several teachers made comments on the programs or instruction during the visits. They inquired about the availability of other software (besides the first two packages) and told about problems with operating the various programs. One commented on the improvement in group relations resulting from the experience of working together on the computer. Another questioned the validity of the tests being used because they were "word tests" while the tasks on the computer used mainly figures. Several said the students really enjoyed working with the programs but tended to get bored after two weeks or so with the same program.

Eight of the twelve visits to worksheet teachers incorporated observations of instructional sessions. All worksheet sessions involved some sort of class discussion led by the teacher and centered on a worksheet exercise. About a fourth of the sessions involved checking of answers students had worked out previously. Most of the sessions consisted of group work rather than individual work. Because of the lack of an answer key, there was sometimes confusion among teachers as well as students about correct answers. Also, on at least two occasions, it was observed that teachers had some difficulty in expressing why incorrect answers were incorrect.

One teacher had made overhead transparencies of all the figures used on the worksheets so that they could be flipped and rotated as the students watched.

Some of the worksheet teachers made comments regarding the study procedures and materials during the monitoring visits. Several said that their students enjoyed the worksheets and found them challenging. One teacher said that the instruction took a lot of time from other school subjects.

Debriefing Meeting

Two of the three worksheet teachers and all three of the computer teachers attended a debriefing meeting on April 11. The microcomputer consultant led the meeting and recorded the teachers' comments. Teachers were invited to share their reactions to the procedures used in the study, the materials, the design, and any other aspect about which they had opinions.

With respect to procedures, all teachers but one stated that they had used only class time for the visual-spatial instruction. The other teacher had scheduled some students at lunch time in order to fit everyone in. The others fit the computer and worksheet activities in by leaving out activities with other software which they might otherwise have used in conjunction with specific subjects.

Some teachers felt that too much time was taken away from the academic areas. They suggested doing such a study within the subject-matter areas so as not to cause this problem.

The teachers generally agreed that the time period chosen for the study was poor because it occurred during a time which they regarded as being optimal for them to accomplish much of the regular curriculum. They suggested a before-Thanksgiving time as an alternative.

The teachers remarked that the tests given pre and post did not test what had been practiced by the students. The computer teachers particularly felt that the dynamic skills used in the computer instruction would not transfer well to written tests. The teachers also said that more specifically visual-spatial problems re needed.

Several teachers reported that they had felt nervous when their classes had been visited by the research and microcomputer consultants from IER.

The two worksheet teachers felt there had not been enough structure for the worksheet groups in terms of how to deliver or how to schedule the instruction.

Several computer teachers spoke of difficulties in scheduling computers for use by their students during the study. Regarding the software used, they felt "Jigsaw Jenerator" was the most challenging, and "Flip Flop" the easiest. They also had all found at least one flaw in the "Flip Flop" program.

Tests

Although data were collected from 198 fifth graders, 54 of these cases were missing one or more pieces of information. Thus 144 cases were usable in the statistical analysis.

Figure 2 presents the means for each of the treatment groups on each of the (pretests and) posttests. The means used have been adjusted for the effects of the covariates. (Observed means for each class are reported in Appendix B.) Means for the New Jersey test and the spatial test are in raw score units. Maximum scores for these tests were fifty and seven, respectively. Means for the Sequences and Analogies tests are in scaled score units. Maximum scores were 713 and 703, respectively.

FIGURE 2

	GROUP		
Test	Computer	Worksheet	Control
New Jersey	(35.72) 37.11	(36.02) 37.18	(35.51) 37.54
Spatial	(6.15) 6.33	(6.04) 6.46	(6.14) 6.46
Sequences	(550.38) 637.28	(526.23) 608.99	(542.02) 636.62
Analogies	(540.14) 644.59	(526.00) 629.64	(534.39) 655.98

Multivariate tests of significance were performed for each of the factors in the design: group, sex, and school. The tests indicated that the effects of group and sex were nonsignificant. Nonsignificant means that the variations in the posttest scores from computer group to worksheet group to control group, and from male to female, were so small that the most reasonable explanation was chance variation. The effect of schools, on the other hand, was statistically significant.

Statistical significance, which is that level at which the "chance variation" explanation becomes untenable, is commonly defined as occurring when the probability value associated with the statistical test is smaller than .05. The probability values for the tests of all three effects are presented in figure 3.

FIGURE 3

Effect	Probability
Group	.362
School	.008
Sex	.408

DISCUSSION

The absence of a significant effect for either the computer group or the worksheet group over the control group may be attributed to a variety of factors. The present research does not tell us which one or combination of these is in fact the cause, but may allow us to judge which are most reasonable in the light of the other results of the study (time logs, monitoring visits, and debriefing).

The fact that the instructed groups (computer and worksheet) did not show any greater achievement than the non-instructed group, while all had consistent patterns of gain from pre- to post-test (see Appendix B), strongly suggests that the testing detected a maturation effect, which would of course be common to all fifth graders. Recall that the teachers had criticized the tests as not appropriate for the skills taught. These results seem to suggest that what was tested was the development of broad reasoning skills which were not affected by the acquisition of specific visual-spatial skills.

The definition of problem-solving as visual-spatial skill focused on a narrow area, but underlying the selection of the tests was the assumption that such skills would transfer to more general thinking and reasoning skills, particularly those that used a figural medium. This assumption may have been incorrect. The one test which was most closely related to the tasks students practiced was the seven-item spatial test. However, pretest scores on this instrument were so high that students had no opportunity to display further achievement on this type of items.

Another possible cause of the nonsignificant effects is the lack of consistent treatments over the course of the study. However, the monitoring visits and the logs indicate that for the most part the treatment was given as specified.

The use of the computer software as stand-alone instruction is a third possible source of the non-significant results. Sunburst Communications, the publisher of three of the programs used, has developed a comprehensive problem-solving skills instructional strategy. The strategy is based on a problem solving skill matrix, the components of which are memory, cognitive skills, cognitive control strategies, and creativity. They believe these to be hierarchical in nature, and have thus devised their activities to proceed sequentially from one level to the next. The curriculum they propose integrates problem-solving skills software with classroom activities. The software is "used to reinforce learning and make it fun," while the classroom activities are used to introduce and teach directly the problem solving skills. In the present study, programs were used in a "stand-alone" manner as the primary means of instruction: not only is this contrary to the Sunburst philosophy, it is also an unrealistic pattern of use for a classroom teacher. Different results may have been obtained had classroom activities and teacher instruction been incorporated into a planned sequence of software use.

SUMMARY

This project studied the effect of use of problem-solving computer software on student performance on tests of reasoning and problem-solving ability. This performance was compared with that of students learning the same skills through use of worksheets, and with students receiving no specific instruction in these skills. A quasi-experimental design was used with teachers volunteering to be in the "computer" group, the "worksheet" group, or the control group.

For purposes of the study, problem-solving was defined as being skill in manipulating figures in two-dimensional space (visual-spatial skill). The software and worksheets were selected with this specific area in mind.

Nine fifth grade classes participated in the experiment, with three being assigned to each condition. Meetings were held with teachers prior to the beginning of the eight-week instructional period to insure that all teachers used similar teaching methods. Observation visits were made during the eight weeks to further insure that this was happening.

Each student in a computer or worksheet group received approximately sixty minutes per week of instruction. This was confirmed by the time logs kept in each class. Computer time was generally spent by two or three students working together at one computer. Worksheet instructional time was generally spent in whole-class activities.

The analysis of the test data showed that there were no differences in achievement between any of the three groups. Each group did, however, make gains on each test from pretesting to posttesting.

These results strongly suggest that a common factor, such as maturation or normal intellectual growth, was measured by the tests used. Though students may have made specific visual-spatial skill gains, these were not be detected by the instruments used. Both the comments of the teachers regarding the inappropriateness of the test instruments and an item-by-item content analysis of each test confirm that three of the four instruments addressed general reasoning skill with only negligible opportunity for students to use visual-spatial manipulations. The fourth test did use problems very much like those the students practiced in instruction, but pretest scores on this test were so high that it was not possible for students to demonstrate any significant gains on the posttest.

It is also possible that the use of the computer programs as the primary means of instruction was less effective than using them as a supplement to teacher instruction. Sunburst, the publisher of three of the programs used, advocates an

integrated approach to problem-solving instruction wherein the teacher introduces certain skills which are reinforced through use of the computer programs. Students especially need to be shown how to make the connection between the strategies they devise in order to solve a specific problem, and more generalized problem-solving and reasoning skills. Research on learning has shown that such a transfer does not occur automatically for most students: it must be pointed out by a teacher.

Options for Further Study

New research questions arise as a result of this study which may suggest fruitful directions for future research in District #181. After consultation with the district microcomputer coordinator and microcomputer consultant, the following options are presented.

1. Study problem-solving skill development in connection with the use of LOGO. A review of Seymour Pappert's theories should be the foundation for the study. Ways of using LOGO would need to be standardized to minimize variation due to the knowledge and skill of particular teachers in using this software. Careful attention should be paid to selection of appropriate tests. A similar experimental design could be employed, perhaps at a lower grade level, over a four to eight week period.

2. Focus attention on subject-specific software. Research shows that simulation software in particular helps to increase student scores on tests over subject matter they have been taught. Since both integration of computers into the regular curriculum and the area of science are of current interest in District #181, this combination might provide the setting for a very interesting investigation. This project would require the surveying of currently available science software and comparing it with district science objectives. Again, selection or creation of appropriate tests is also an important consideration.

The purpose of the experiment reported above was to determine whether the computer could be used to enhance development of problem-solving skills. Such enhancement was not demonstrated. However, certain factors such as appropriateness of tests and of teaching methods might have influenced the findings. This realization will be valuable in designing future research studies of the role of computers in schools, not only in District #181 but across the nation.

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APPENDIX A

PROBLEM SOLVING PROJECT DESCRIPTION

Memo to : Fifth Grade Teachers

From : Ann Dana and Nan Simpson

Re : Computer Problem Solving Project

As you know, the district is studying the acquisition of problem solving skills by fifth grade students.

For the prupose of the study, "problem solving" has been defined as skill in solving visual-spatial problems. The ability to mentally manipulate shapes, to perceive relationships among two-dimensional figures, and solve spatial reasoning problems are included in our working definition of problem solving. These skills are among those measured on nearly all IQ and aptitude tests, so the study is an important and interesting one!

All district fifth grade classes have been been assigned to one of three groups:

1. Computer-assisted group. Students will use computer software designed to help students improve spatial problem-solving skills for one hour per week.
2. Worksheet group. Students will use worksheets and do seatwork exercises designed to enhance spatial problem-solving skills for one hour per week.
3. Control group. Students will have no special instruction in problem solving.

ALL students (Computer, Worksheet, and Control groups) will be pre and posttested as follows:

Pretests: New Jersey Test of Reasoning
Wheatley Test of spatial relationships (or similar instrument)

Posttests: Same 2 tests as pretest AND
Test of Cognitive Skills (TCS)

The schedule for the project is:

Week of December 12	Students are pretested (both tests). Total time required is about 1½ hours.
Jan. 12 - March 1	Study in progress. All students in computer and worksheet groups devote one hour/week to problem solving activities. (Separate sheet for each group gives more detail).
March 1	Students are posttested with N.J. Test of Reasoning and Spatial Visualization test. (requires 1½ hours).
During March (date to be announced)	Students posttested with TCS level 2 (requires 1 hour)

Please plan now to test students on dates listed. Note ALL 5th grade students are tested.

Memo to: Teachers of Computer Group

From : Ann Dana and Nan Simpson

Re : Computer Problem Solving project

Before reading this, please be sure to read the PROBLEM SOLVING PROJECT DESCRIPTION.

Your students will spend one hour per week for eight weeks using special computer programs designed to enhance spatial problem solving skills. Arrangements have been made for you to have priority use of the school's available computers. Please contact Ann Dana and your school's LRC director to work out a schedule. The schedule should be completed before Christmas vacation.

Each student should have three 20 minute sessions or four 15 minute sessions at the computer per week. You may group students if necessary, but there should be no more than three or four students in a group. Two or three per group is ideal, with students sharing responsibility for interacting with the computer.

At this time, we expect the computer group to work solely with the computer software. As the experiment proceeds we'll be in touch with you to see if auxiliary worksheets are needed.

Two software packages are now available: FACTORY and JIGSAW. We have ordered two others: FUNHOUSE MAZE and FLIP FLOP. All stress spatial visualization skills in a "game" format.

Ann Dana will schedule time with you to preview the software and plan ways to use it. Once the project begins, you will be asked to keep a log of time spent on spatial skill development by each of your students. A form will be provided for the purpose.

Ann Dana and Nan Simpson (our research consultant) will be in touch with you as the study gets underway. If you have questions, contact Ann.

THANK YOU FOR YOUR HELP! Results will be shared with all teachers participating in the study.

To : Teachers of Worksheet Group

From : Ann Dana and Nan Simpson

Re : Computer Problem Solving project

Before reading this, please be sure to read the PROBLEM SOLVING PROJECT DESCRIPTION.

Your students will spend one hour per week for eight weeks doing special exercises and worksheets to help them improve their spatial visualization skills. Please try to schedule the hour per week as three 20 minute sessions or two 30 minute sessions. You will be asked to keep a log of time expended which specifies the amount of time spent by each child. A log form will be provided for this purpose.

You will receive 24 sets of "lessons" or worksheets. The worksheet sets are numbered and should be used in this order. The 24 sets of worksheets will suffice for three sessions/weed for 8 weeks if you use one set per lesson. If you plan two half-hour sessions you'll need to use about 1½ sets per lesson.

Each set of worksheets is accompanied by brief tips for using. You need not follow the tips exactly. However, please try to include in each lesson the following steps:

1. Teacher explanation of main idea of the lesson ("looking for differences"; "looking for patterns", etc.)

2. Working through one or two examples with whole class

3. Time for students to work individually on several examples

and/or

4. Group work. This could be class discussion, or a short exercise in which pairs of students each construct an exercise for the partner to solve. An alternative exercise for some lessons might be to practice with cutout shapes.

Be sure to spend the designated one hour per week on these activities! Very little information has been published regarding the effectiveness to teach spatial problem solving. Your work with your students is an important part of the study.

Ann Dana and Nan Simpson (our research consultant) will be in touch with you as the study gets underway. If you have questions, contact Ann.

THANK YOU FOR YOUR HELP! Results will be shared with all teachers participating in the study.

Memo to : Teachers of Control Group

From : Ann Dana and Nan Simpson

Re : Computer Problem Solving project

Before reading this, please be sure to read the PROBLEM SOLVING PROJECT DESCRIPTION.

Your students are in the control group. This means they will have no special problem solving instruction for the eight weeks beginning January 3.

Since your students will provide important comparison data, they will be pretested and posttested according to the schedule given in the Problem Solving Project Description.

After March 1, if you like, you will be free to use the problem solving software and/or the worksheets. Also, you will receive results of the study once the data analysis is complete.

THANK YOU FOR YOUR HELP!

PROBLEM SOLVING LOG
WORKSHEET GROUP

This log form is to record all problem-solving sessions you conduct with your class. There is a space representing each day of the week for each week of the problem-solving study. Complete the log by filling in the number of minutes your class spends on problem-solving worksheets and exercises for the appropriate days.

Son. students may be absent on the day the worksheets are used. Please write on the lines at the bottom (continuing onto another sheet if needed) the names of students missing problem-solving lessons, the date of the missed lesson, and whether the student received a make-up lesson. (It is not necessary for you to give a make-up lesson, but we need to know for each student the total amount of time spent on problem solving activities).

WEEK OF	MON	TUES	WED	THURS	FRI
Jan 3					
Jan 9					
Jan 16					
Jan 23					
Jan 30					
Feb 6					
Feb 13					
Feb 20					
Feb 27					

Students missing lessons

Date	Name	Made up lesson?	Date	Name	Made up lesson?

Continue on separate sheet if needed

PROBLEM SOLVING LOG SHEET
COMPUTER GROUP

It is important to know how much time was spent bv each of your students on problem-solving activities. Please complete one log form each week (we'll supply xeroxed copies with your class list to save your time). Each time a student spends time with the problem-solving software, write the number of minutes in the appropriate day-specific space. in parentheses, write the number of students working together if students worked in small groups. An entry might have the form 20(3) for example if a group of 3 students had a 20 minute session at the computer.

WEEK BEGINNING ____________________________

STUDENT	DAY: MON	TUES	WED	THURS	FRI

APPENDIX B

OBSERVED SCORES FOR COMPUTER, WORKSHEET, AND CONTROL CLASSES

	Tests							
	New Jersey		Spatial		Sequences		Analogies	
	pre	post	pre	post	pre*	post	pre*	post
Computer Classes								
1.	37.12	39.85	6.2	6.7	541	653	563	678
2.	33.42	34.78	6.0	6.3	541	600	[illegible]93	542
3.	36.12	37.52	6.2	6.2	562	642	551	669
Worksheet Classes								
1.	33.25	34.78	6.2	6.1	526	587	526	607
2.	38.15	38.48	6.2	6.5	521	610	526	603
3.	37.47	38.50	5.6	6.4	533	613	526	632
Control Classes								
1.	37.71	38.09	6.4	6.4	535	640	557	641
2.	36.65	40.65	6.2	6.6	557	648	531	633
3.	32.43	34.92	5.7	6.4	533	617	508	661

* estimated from percentile ranks