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AUTHOR	Weber, Jennifer
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ABSTRACT

Problem solving is applicable to all grade levels and subject areas. This study focused on the development of problem-solving skills in fifth grade students using problem-solving software. A pre- and post-test were administered to 21 fifth grade students. Four students were chosen for the treatment group and four for the control group. The treatment group was given 7 weeks of instruction using problem-solving software appropriate for their age. Observations showed a positive change in all the treatment students' actions with and feelings toward computers and problem solving. Cognitive assessments were inconclusive. The appendix contains 20 lesson plans for the computer unit, strategies and difficulties with each of the software programs, and the pre-test and post-test designs used. (MKR)

Development of Problem Solving Skills: Fifth Grade Students Using Software With Assistance Versus Students Without Assistance

Jennifer Weber

The Ohio State University: Mansfield

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Deve!opment of Problem Solving Skills:

Fifth Grade Students

Using Software With Assistance

Versus Students Without Assistance

A central goal of school mathematics programs has been the development of problem solving skills as the National Council of Teachers of Mathematics reported in their Agenda for Action (1980) and their Curriculum and Evaluation Standards for School Mathematics (1991).

> The most significant change in the curriculum of the next ten or twenty years will be to place emphasis on realistic, non-routine problem solving. Most recently the National Council of Teachers of Mathematics (1980) issued recommendations regarding the teaching of problem solving. A key feature of those recommendations is that the curriculum be organized around problem-solving with instruction in a broad range of strategies and processes. The movement toward the use of problem solving strategies and processes is not confined to any one discipline. In light of our technological capabilities, mean developing problem-solving skills.
> Eileen K. Gress, The Computing Teacher, September 1981.

Many studies done since 1970 have supported the idea that problem solving needs to play a central role in school mathematics programs. Likewise, many studies have linked the teaching of problem solving with computer programs designed for that purpose.

Ohio's Model Competency-Based Mathematics Program (Ohio Department of Education, 1990) highlights problem solving as one of eight strands that need instruction and attention in the K-8 mathematics curriculum. Problem solving skills are to be applied in other strands so children can realize how problem solving skills are used in every subject in school and in their everyday lives.

Problem solving is applicable to all grade levels and subject areas; this study focused on the development of problem solving skills in fifth grade students. With the goal of helping children become better thinkers, the research project focused on how problem solving software could help a teacher enhance the experience of every student because every student is a unique individual with individual needs.

Statement of the Problem

The problem addressed in this research project was 'How are problem solving skills developed by fifth grade students who extensively use problem solving software supplemented with instruction different from problem solving skills developed by fifth grade students not receiving instruction?' By assessing what students understood about the problem solving skills that were used in the computer software and the procedural skills that were needed to use the computer software, relevant instruction addressing those skills was developed. This study is significant because the results will indicate whether changes need to occur in the current instructional practices when computers are used to enhance students' problem solving abilities. Do the skills and procedures new to students need to be taught so that students receive the optimum benefit from using the software to enhance their learning?

Review of Related Literature

Problem solving has become a goal of education, for all students, in recent years. Learning effective problem solving skills prepares students to be successful citizens as they learn how to think and problem solve in many different ways. We must provide every student with ample opportunity to acquire the skills which will promote success in our rapidly changing world (Stearns, 1986).

Suggestions from research state that one should teach the underlying cognitive abilities such as memory and the recognition of similarities and differences and that one should teach the knowledge base and specific problem solving strategies as well (Frederiksen, 1984). The *Professional Standards for Teaching Mathematics*, which was printed by the National Council of Teachers of Mathematics stated that:

> Teaching mathematics from a problem-solving perspective entails more than solving non-routine but often isolated problems or typical textbook types of problems. It involves the notion that the very essence of studying mathematics is itself an exercise in exploring, conjecturing, examining, and testing--all aspects of problem solving. Teachers should engage students in mathematical discourse about problem solving.

Additional evidence that NCTM is concerned with the problem solving aspect of mathematics can be found in the *Curriculum and Evaluation Standards for School Mathematics*. They support the application of problem solving in the mathematics curriculum:

> When problem solving becomes an integral part of classroom instruction and children experience success in solving problems, they gain confidence in doing mathematics and develop persevering and inquiring minds. They also grow in their ability to communicate mathematically and use higher-level thinking processes.

While educators and researchers recognize and value the benefits seen through the use of problem solving and computer use in the classroom, it is still being researced as to why computers are such a great learning aid to students.

Although little has been done to show exactly why computers help students learn more, retain more or learn the same amount faster, studies have been conducted to show that the gains made by students who have access to computers are very evident. In studies conducted by the Educational Testing Service (ETS), it was found that in mathematics, children who had access to the computer for only 10 minutes a day to work on drill and practice in mathematics scored significantly higher than those who did not have such access. Twenty minutes a day doubled the gain, and as the study progressed, ETS found that the children increased these gains over those with no access (Bracey 1982).

In general, students learn more, retain more or learn the same amount faster using computers (Bracey 1982). Perhaps a reason for the success students achieve with having the computers as a teacher lies in the computer's patient, non-critical tutoring and support of the student's learning. "Achievement gains aside, students often find computers more 'human'--more patient, less critical--than humans" (Bracey 1982). This affective support allows the child to guide his/her own learning and focus on his/her own strengths and needs.

Since the increased interest in using computers in instruction in the 1980's, there has been a switch from thinking only of computers as an aid to drill and practice and instead, thinking of them as facilitators to aid children's problem solving abilities. Many programs have been specifically designed for this purpose. Marilyn N. Suydam, a strong supporter of using microcomputers in the classroom, states, "Extensive work on problem solving using the computer enhances an understanding of mathematics topics and aids in developing strategies" (1984).

Problem solving can be taught (Suydam, 1982). A meta-analysis of problem solving done by Frederiksen (1984) supports the idea of teaching problem solving and indicates that specific strategies must be addressed in teaching problem solving. Stearns(1986) took the idea of teaching problem solving to children and extended it to teaching those skills with the aid of computer programs. Stearns concluded that the computer is a valuable aid in teaching problem solving skills because the computer is a highly interesting and intrinsically motivating medium. Riedesel and Clements (1985) found that the computer aided in the instruction of problem solving by emphasizing computer programs' provisions of carefully sequenced activities, finely tuned task difficulties, and controlled feedback.

The methods of the study follow.

Methodology

Sample

This study was conducted in a fifth grade classroom of 21 students (four students each, treatment group and control group) in North Central Ohio between January and March of 1993. All students were from a rural area and were from households of average to low income. Several students with special needs were meeting with a tutor and a learning disabilities teacher; these students were not in the treatment group or control group.

In a conference with the classroom teacher, the researcher categorized the class into four groups: high ability, medium ability, low ability, and those who were felt to have math anxiety. Before the project instruction began, four students were randomly selected for the treatment group. After conferencing with the classroom teacher, the students were paired according to different ability levels in mathematics. After the treatment and after the pre and post test had been administered to the class of 21 students, four students were randomly chosen from the remaining 17 class members to serve as the control group.

This selection process ensured that the researcher would not inadvertently clue these four students that their actions were being observed more than others. Their time on computers and their pretest and posttest results were compared to the four students in the instructed set. The students in the treatment group will be known as follows:

TABLE 1--Identification of Students in the Treatment and Control Groups

—	Treatment	Control
Anxiety	T1	C1
Low Ability	T2	C2
Medium Ability	T3	C3
High Ability	T4	C4

The two groups were representative of the ability levels of the population in the whole grade level within the school district. They are also typical of the four categories in the student population in the district. The high, medium, and low ability groups denote students who are consistent in their work in the classroom and on their results on test work. The math anxiety grouping takes into account students whose quality of work in the classroom is not reflected in their test scores for whatever reason.

A discussion concerning testing, the computer software used, and the manipulative materials used in the study follows.

Instruments Used

The pretest and posttest (see Appendix C), consisted of two parts each, and were given to 21 students in the class. The first part used the Problem Solving and Measurement subtests of Key Math, a diagnostic inventory of essential mathematics (Connolly, 1988). The second part asked students to problem solve in an interview with the researcher to further assess their problem solving abilities. The posttest consisted of questions of a similar design.

The students used Commodore 64 computers and problem solving software that was available in the district for those computers. The programs that were used were: The Pond, The Factory, Gears, and Safari Search. Many pieces of software were evaluated by the researcher to determine their problem solving emphases (see Appendix B). Grade and ability levels were evaluated so appropriate software would be selected that would enhance the students' learning but not frustrate them. The four pieces of software, which were selected, help develop problem solving skills which are identified in the Ohio Model Curriculum (1990) as goals for students in grades 4, 5, and 6: using manipulative materials, using trial and error, making organized lists and tables, drawing diagrams, looking for patterns, and acting out a problem.

Manipulative materials that were used during instruction time with the students, such as square pieces of paper for use with The Factory, were left in the classroom for student use while they were working with the computer. See Appendix A for materials needed in the lesson plans. The materials were available for the control group, although they did not have instruction with them.

Treatment

Week One of the project involved pretesting all the students and selecting the treatment group. During Weeks Two through Five, the researcher spent 45 minutes each day instructing the treatment group and helping them with their work on the computers. Throughout Week Six, the students were allowed to work on the program of their choice. Week Seven involved posttesting all the students and randomly selecting the control group so analysis of the results of the project could begin; the computer software used for the project was removed from the classroom so no student had extra work time before completing the posttest.

Instruction related to using computer software was given before introducing the children to the programs in order to get them past 'glitches,' including procedural knowledge about using a computer and conceptual knowledge that has not been previously learned by the students and which may prevent them from achieving the real goal of developing their problem solving abilities by using the problem solving software (see Appendix A for lesson plans). These 'glitches' were determined by working through the programs and by watching the students work. Discussion and instruction on different problem solving strategies supplemented and extended their work on computers. The instruction was given only to the treatment group so an analysis of how instruction can aid in the development of problem solving skills could be made.

Instruction was given to help the children focus their attention on the similarities and differences between problem solving strategies and the problems that are best solved by using each strategy. The instruction was aimed directly toward procedural and conceptual areas of using the software that may deter students from achieving the benefits of using the programs. The instruction helped clarify what the program was asking them to do and how they were to do it. With probing questions from the researcher, the students had help analyzing what cognitive processes and problem solving skills they were using with each computer program. The instruction generally included: 1.) the introduction of what the computer would ask them to do, 2.) practice, with any previously unlearned conceptual knowledge that is used in a particular software, before going to the computer, and 3.) help with how the computer program runs (keys used, procedures used, how to get information or change to a new problem,...).

During Weeks 2-5 of the project, a new program was introduced each week. The treatment group members would use only the new program during the four hours of lab time with the researcher but were permitted to select their preferred program, from the ones already presented in the project, at other times. During instruction time, students changed partners to allow each child to work with a different student each time. This strategy was to help present the child with situations that would expose him/her to different strategies than those with which the child was most familiar. During the Sixth Week of the project, the students were permitted to work on the programs of their choice even during the time with the researcher. No instruction was given during this week.

Data Collection

In addition to pretesting and posttesting, using a standardized test and a structured problem solving interview, the following methods were used to collect data: student journaling, informal interviewing, audio taping of the formal problem solving interviews, and video taping of 'work' sessions at the computer. Discussion of each method follows.

The students were asked to reflect in journals about what they were learning, what was becoming easier for them, what the first thing is that they do when they have a problem to solve, and other questions pertinent to problem solving. Interviews would supplement the journals when some of the students' ideas needed verbal clarification by the researcher. The discussions with the students and their work at the computers were to be recorded on video tape for later review. Through the journals and discussions, the development of problem solving skills of the students who received instruction were then compared to students who received no such additional help. The taping provided data, from the actual work sessions, for reflection and analysis.

Analysis of Data

The analysis for the Key Math assessment was gained from a norm-referenced rating using the child's age at the time of the test to obtain a scaled score. These scores were compaired to the mean and standard deviation scores of grade-based scaled scores and age-based scaled scores.

The other problems in the problem solving interviews were holistically rated on a scale from zero to three. Table 2 shows the rubric which was developed to rate students' responses to the questions posed during the problem solving interview with the researcher.

TABLE 2--Holistic Rubric Used to Score Responses in Problem Solving Interview

Rating	Nature of the Response
3	The child used a strategy giving the correct solution with three or more other strategies given, showing complete understanding of the problem.
2	The child used a strategy that showed an understanding of what was being asked.
d	correct answer/alternative solution/s given
c	correct answer/no alternative solution/s given
b	incorrect answer/alternative solution/s given
a	incorrect answer/no alternative solution/s given
1	The child worked on a visual level of understanding and/or showing no understanding of the problem.
0	The child gave no answer.

The results fo the study follow a discussion of the limits of the study.

Results

Limits of the Study

The lack of video equipment for this study was a limit to the amount of data the researcher could obtain to determine affective changes in the students and to help determine students' overall growths. The time the researcher was in the classroom limited the observation of students' actions and reactions with the computers. It was hoped that the use of video equipment would prevent bias.

Time also limited the assessment that was done because the whole class was being tested. There was not sufficitent time to administer the entire Key Math test, which may have been a help when analyzing the results and the changes in the students.

Students' lack of experiences in journaling was a limit to the study; entries were sparse. The researcher introduced the entire class to the journal activity and completed entries with the students, but their lack of experience prohibited them from continuing independently. Therefore, the information obtained from journals was not sufficient to provide any insights concerning the computer and software use.

The lack of completed journal entries was a big limit to arriving at any conclusive results as the journals were where the students logged not only their thoughts about the computers that day, but also their time on the computers. Without these time logs, the results of the tests could not be compared to the time the students were on the computers.

Findings

The results of the pre and post tests, from the Measurement and Problem Solving Subtest from Key Math, for the students in the study are reported in Tables 3 and 5. Table 6 identifies affective changes, which occured with the students in the study, as observed by the researcher.

TABLE 3--Pre and Post Test Results--Key Math Scaled Scores (Pre/Post Scaled Score)

	Treatment				Control			
	T1	T2	T3	T4	C1	C2	C3	C4
Measurement	9/9	9/10	13/11	9/10	5/5	6/5	10/11	7/9
Prob. Solving	9/7	1/7	11/13	8/12	4/5	6/6	14/13	8/10

TABLE 4

Means and Standard Deviation of Grade-Based Scaled Scores and Age-Based Scaled Scores

	Grade Norms	Age Norms		
	Fifth Grade	10 yrs.	11 yrs.	12 yrs.
Measurement	10.2 (2.8)	9.8 (2.4)	10.5 (3.0)	10.0 (3.0)
Prob. Solving	9.8 (3.1)	9.3 (3.4)	10.0 (3.3)	10.2(3.3)

The results from the Key Math subtests were mixed, some showing positive results and some negative results. Because there is no consistent pattern in the students' scores, it is not clear whether these subtests really tested the results of the work the students did with the programs and their consequent growth. The students' scores (Table 3) were used to provide a comparison of pre and post treatment responses on a norm referenced test (Table 4). The results of the students were analyzed by subtest comparison to Grade-Based Scaled Scores and Age-Based Scaled Scores. Not all students in either the treatment group or the control group were at grade level or made great gains toward that level during the project.

TABLE 5

Pre and Post Test Results--Problem Solving Interview Holistic Scores (Pre/Post Holistic Score)

	Treatment				Control			
	T1	T2	T3	T4	C1	C2	C3	C4
Question 1	2a/2a	1/2e	2a/2a	2c/2a	2a/2a	2c/2a	2c/1	1/1
Question 2	0/1	2a/2a	2a/2a	2c/2a	2c/2b	2a/2a	2a/1	1/1
Question 3	2a/2a	2c/2a	2c/2d	2c/2c	2c/2d	2d/2a	2b/2a	1/2a
Question 4	0/0	2c/2c	2a/2a	2c/2b	2c/2d	2c/2b	2d/2d	1/2a

As with the results of the Key Math testing, the results here are mixed and so deter any definite conclusions from being formed. When comparing Tables 3 and 5, it can be seen that even though a student may be seen to make positive gains in Table 3, for example student T2, that same student's results do not demonstrate the same consistency in Table 5; again, this limits the analysis of the testing results. The question must be asked again, 'What did the test measure?' In looking at both Table 3 and Table 5,there is only one student, C4, who shows a strong consistency, but this positive result is limited as conclusive evidence because of the inconsistency with that child's peers' scores; C4 is the exception rather than the rule. This is a case study; four people is too small a group to make a 'rule.'

TABLE 6

Affective Results

Treatment	Control
•more on task behavior at computer	•observed more play behavior, not working toward goals of the program
•used more/varied strategies during testing (i.e. using paper, drawing pictures)	
•generally better at discussing the software and strategies used	
•always eager to redo a problem on the computer until done correctly	•not bothered by not getting a problem correctly, would go on to the next

The affective observations showed a positive change in all the treatment students' actions with and feelings for computers and problem solving. The most noticed change in the students in the sample group was in their manner of attacking problems and, additionally, in their reactions toward the computers themselves. They became more aggressive in their working with a new program near the end of the project period.

Discussion

The most important aspect to consider when trying to analyze the results is the fact that the children were only exposed to the programs and the instruction with the teacher for a very short five weeks. During this time, they were not given unlimited time on the computers as they had their other classwork to complete.

It was predicted that the students who engage in discussion and analysis, with the researcher and other students, on how they are approaching and solving problems will see a more marked increase in a better ability to approach and solve problems. Also, it was predicted that the additional instruction and guidance from the researcher to the four case study children would further help their chances of success with the software problems. I hesitate to say that these changes in the students did not occur, although in general, the students engaged in less discussion among themselves than expected as they worked with the different programs and the test results showed no great gains on paper.

These preferred behaviors and results from the instruction need time to mature; five weeks is a very short time to ask students to learn and synthesize the information provided in this project. There is no way of knowing, but if we were to test the students again after giving them sufficient time to synthesize the skills used during those five weeks, we may see stronger positive results.

Implications

The clearest implication I can see from this project is that computer use and problem solving skills must be taught before children can be expected to use them competently and on a regular basis. Even the most simple of computer programs should be introduced with instruction unless the specific goal of the lesson is for the students to work in a problem solving/discovery manner to learn as much as they can about the program.

From the study, there is some evidence that the integration of instruction into computer use and the integration of computer use into other areas of the curriculum are a benefit to students. The students in the study showed much more on task behavior with the software compared to the play activity seen in the control group. The students in the treatment group were more active in attempting problems and in redoing problems on the computer to try and correct where their errors were than were the students who had received no instruction. The focus of attention for the students who were in the treatment group seemed to be on the problem and how to solve it; whereas, the students who were not in the treatment group were more easily distracted by aspects of the programs such as the graphic affects.

The implications of the study are that there need to be modifications made in the study so more conclusive evidence can support the glimpses of growth, especially in the positive changes in students' attitudes, which I saw in the treatment group of students in my project. These glimpses of success in just five short week hint at a much broader success with all students if this study were to be continued over a longer period of time.

Recommendations

If I were to do this project again, I would definitely allow for more time between the introduction of each new program to allow the students ample time to work with and develop the problem solving skills featured in each program. I would also allow much more time for discussion, whether whole group or small group, as the students I worked with had not had much experience with discussing computers and skills that they are developing.

In order to better document students' reactions to and interactions with the computer programs, video equipment needs to be set up all the time so it is ready when needed. Also, the journals were an idea that could work to record the students' changing growth during the project, but they need ample experience and/or tutoring to help them in writing in their journal. My students were not familiar enough with writing in journals, especially on the topic of using the computer.

If this research study were to be done again, I think there should be some changes in the format of the testing as our tests did not prove nor disprove any of our goals for the study. It may work to use the whole Key Math test to see a more global picture of the students' growth. Another aspect of the study where it would be interesting to document the students' ideas is in the area of changing attitudes toward math and computers. There are tests available that could be used for a pre and a post test to document any changes in attitude that may be the effect of the study.

I believe that the project and its findings were very worthwhile as they reinforce the idea that computers and problem solving instruction can no longer be treated as an extension of learning but must be incorporated into each child's learning experience in order to enhance and help develop children's problem solving skills in a way that the text materials and the teacher cannot.

Appendix A

Computer Unit (20 lessons)

For Commodore 64 Computers
And Problem Solving Software
In a Fifth-Grade Classroom

These lesson plans were written for and implemented in a fifth grade classroom in a rural middle school in North Eastern Ohio. The classroom consisted of 21 Caucasian children of families with average or below average incomes. These lessons were done with a small group, four students, as part of a study but could easily be adapted for use with a larger group or a whole class. In addition to the lessons, computer journals, interviews, and videotape of the students using the computer were used with all the students to record their feelings and ideas as they worked through more and more problems on the computer. The journals were just papers staples into a booklet form with a cover page decorated by the students.

Four Lessons with The Pond

Materials:

computer	graph paper (1cm) for each student
The Pond	pencils
TV monitor (Lesson 1 and/or 2)	

Lesson One:

1. Using graph paper with squares of 1cm or larger, have the students invent paths, from one side of the paper to the other, that have repeating steps.
2. Run through an example with the students before allowing them to try and trick a partner with their own pattern across the paper.
3. Remind the students that just like a game board, you do not count the space that you are on when making a move.
4. Introduce the students to procedures used in the pond that may unfamiliar to them such as the notation used to show the different steps of the pattern (↑2→4) and the buttons used to move the frog. Also introduce them to the function buttons F1 and F3, which allow them to use different strategies in discovering the patterns.
5. If time allows, hook the computer to a TV monitor so all students can see and work through one pattern on the computer with the children so they can see the steps through which they solve the pattern problem, enter their solution, and test their solution.

Lesson two:

1. If you have not already worked through one or more patterns on the computer with the children, do so before allowing the students to work in groups at the computers.
2. Allow them free exploration of the program today.

Lesson three:

1. Ask that each group at least attempt a medium level problem today.
2. Before the end of class, pose the question as to why we need to learn how to solve patterns and what purpose patterns play in our lives. Ask the students to bring their suggestions to class the next day.

Lesson four:

1. Ask that each group attempt at least one high level problem on The Pond before allowing them to choose what level they want to play at.

Five Lessons with The Factory

Materials:

computer — The Factory
pencils — paper squares for each student
TV monitor (Lesson 1 and/or 2)

Lesson one:

1. Have the students stand to practice rotating a certain number of degrees. Using turns of degrees 45, 90, 135, 180, 360, practice with the students.
   •Call out a direction to turn and the number of degrees (ex.: 'left 45 degrees') and wait for each student to turn and check his/her accuracy with the rest of the students positions.
   •Call several more before allowing students to call out turns.
2. Once the students are familiar with rotating their bodies, use a paper square, which is large enough for all the students to see clearly, to imitate rotations of a piece of paper.
3. Next introduce the actions of adding stripes (with marker) and punches (draw a circle or square with a different colored marker) as the paper is rotated however the students specify. •Write the directions the students give on the board in the manner that The Factory uses to familiarize the students before they go to the computer.
4. Have the students imagine and act as if the paper is going through a machine. Depending on the age of the students and how concrete you want the experience to be, you could actually build the different machines out of boxes and have an assembly line factory.

•It is beneficial for the students to do several examples on paper together before going to the computer. If the students need more practice after doing several examples on paper as a class, they could work in pairs.
•Also, during computer time with this program, if there are not enough computers for the whole class to work in pairs at the computer at the same time, some students could work at making factories on paper and trying to trick their partner.

Lesson two:

Lesson one may overlap into lesson two depending on the time you have and on how quickly the students pick up on what is introduced in Lesson One.

1. After reviewing what was learned in Lesson One, allow the students to go to the computers to experiment with the section of Testing a Machine.
2. Regather and connect the computer to the TV monitor so all students can see and work through several an example each of Making a Product and Building a Factory.
3. Have the students volunteer what is to be entered in the computer

each time.

4. Have the students switch who enters the answers for the class.

Lesson three:

1. Again, review to make sure all the students remember what is going on.
2. Have the students work in pairs, preferably different partners each time they go to the computer so experience working with different problem solvers; this will also develop their interpersonal communication and cooperation skills.
3. Encourage the students to work in the Make a Product section today.

Lesson four:

1. Review and ask students to share with their classmates what they are finding out about the program and how they are solving the problems.
2. Encourage the students to Build a Factory and challenge their partner to make the product that results.
3. Ask each of them to write their steps down so they can compare after the second partner has solved the problem. •Steps may differ in both number of them and the order of them.

Lesson Five:

1. After review and sharing of what the students are finding out about the program and their problem solving strategies, allow the students to choose what section of The Factory they will work in today.

Five Lessons with Gears

Materials:

computers	Gears
paper examples of gears	real examples of gears
scrap paper	pencils

Lesson one:

1. Allow the students to play with the paper gears and the real gears.
2. Focus their attention with questions to try and get them to notice different items:

•the same number of teeth 'go by' on each gear
•the number of times the gear has to turn depends on the size (diameter) of the gear
•the number and size of gears in the middle do not matter, only the first and last gear
•the gears in between only affect the direction the last gear is turning

3. Really have them focus on different situations where the first and last gears change (large to small, equal size to equal, small to large).
4. Have them try and hypothesize and experiment with an equation that would help them solve the problems.

Lesson two:

1. Without having told them the equation, let them experiment on the computer in Making a Gear Chain; have them write down their guesses, as to how many rotations the last gear will do and which direction it will be turning, before they tell the computer to do the work.
2. Again, have them working in pairs. As this is a fairly frustrating topic to see and think about, you may even want to put three students in each group.

Lesson three:

1. Regather and have the groups share what they found.
2. Let the students actively problem solve for a while with as much discussion as they need.
3. Help them formulate the formula before today is over.

Lesson four:

1. Encourage the experimentation and manipulation of the equation by the students in order for them to use it easier, yet still correctly.
2. Computer work in Solving a Gear Problem.

Lesson five:

1. Discuss ways the different groups found to use the equation more easily.
2. Computer work in Making a Product.

Four Lessons with Safari Search

Materials:

25 small containers, such as empty camera film cases

paper — pencils

computer — TV monitor for Lesson 2

Safari Search — small object that fits under container

Lesson one:

1. Set up the containers on a table in a 5x5 square with the object hidden under one.
2. Explain to the class that when they ask about a particular container, you will tell them if you can 'see' the object in either that row or column (use several other ways that the computer uses to give clues also).
3. Be asking questions: 'What does that tell us?'; 'What do we know?'; 'Can we eliminate any?'; 'Can we see better where the object is?'....
4. Allow for student questions and confusion; do enough examples that not all the students are still confused.
5. Ask the students who understand to share their strategies and their thoughts.

   •With the objects, you can let the students remove the ones they know do not contain the object; this may help the confusion as they can actually see the elimination happening and see the choices narrow down.
6. If time allows, do the same exercises on paper, the students will see another representation of the problem and will have to come up with another strategy for showing what has been eliminated (x-ing out,...).

   •Using paper will give them a strategy for drawing a representation of the computer screen when they get to that point in the next lesson to help them remember what they have eliminated.

Lesson two:

1. Review and do more examples with whole class if necessary.
2. Hook up the TV monitor and work through several different examples on the computer with the whole class, letting the students volunteer their answers and enter them in the computer.
3. Pair them up for working on computers.
4. Encourage them to work in any of the first six problem areas on the computer.

Lesson three:

1. Review and share what was discovered yesterday on the computers.
2. Discuss what worked and what didn't; let the students help each other.
3. Again focus them: 'Why do you think what you were doing didn't work?...did work?'....
4. Repair and work in problem areas 7-12.

Lesson four:

1. Allow the students their choice with what area they want to work in in <u>Safari Search</u>.
2. Regather for any more comments the students want to share.

Appendix B

Strategies/Difficulties with the Programs

Software	Analysis	
The Pond	Strategies:	•Looking for a Pattern or Sequence •Information Gathering
	Difficulties:	•Working With Repeating Patterns •Using Keys to Find Pattern •Entering Solution in Computer
The Factory	Strategies:	•Working Backwards •Analyzing •Looking for a Pattern or Sequence
	Difficulties:	•Rotation Degrees •Entering Solution in Computer
Gears	Strategies:	•Identifying Multiple Solutions •Working Backwards •Using a Model •Analyzing •Looking for a Pattern or Sequence •Information Gathering
	Difficulties:	•Understanding How Gears Operate •Entering the Solution •Recording Attempts/Results
Safari Search	Strategies:	•Looking for a Pattern or Sequence •Information Gathering •Analyzing
	Difficulties:	•Keeping Track of Clues Given •Understanding the Clues

Appendix C

Pretest and Posttest Designs Used

With both the pretest and the posttest, the following materials were present on the table for the student to use if he/she chose to:

graph paper

pencils

drawing paper

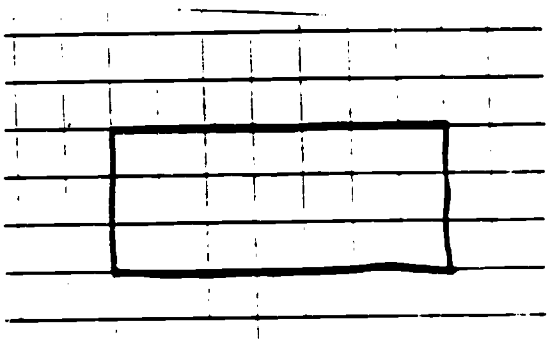
unifix cubes (same size as geoboard and graph paper)

Questions were repeated at the student's request. No response was given to any student as to the correctness of his/her answer.

Pretest

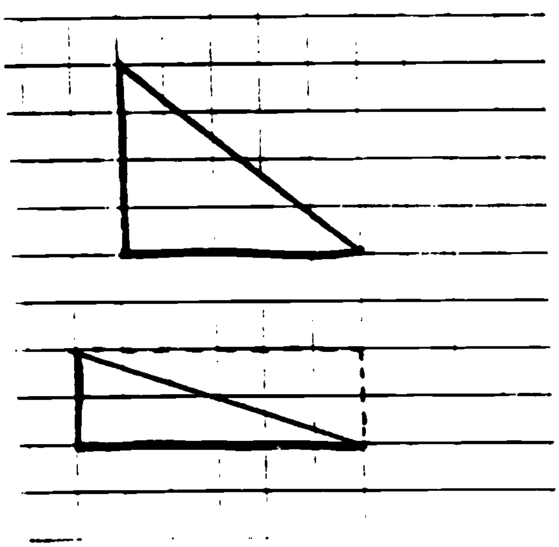
I. Key Math subtests, Measurement and Problem Solving

II. Questions with a Geoboard:



I used 21 units to cover this shape.

(Cover a rectangle with 21 units.)

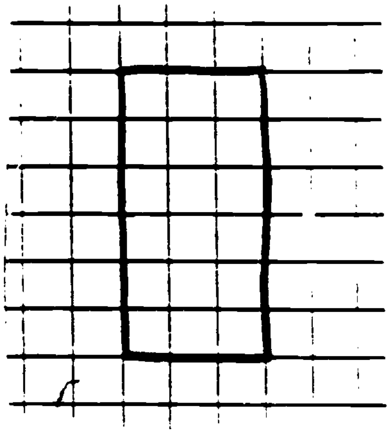


How many units would it take to cover this shape?

What did you think about as you answered the question?

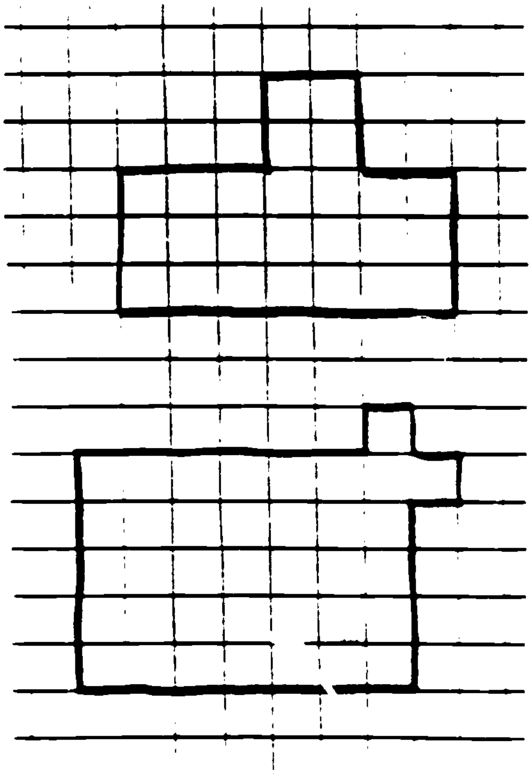
What other ways could you have gotten an answer?

III. Questions with Graph paper:



I used 18 units to cover this shape.

(Cover a rectangle with 18 units.)



How many units would it take to cover this shape?

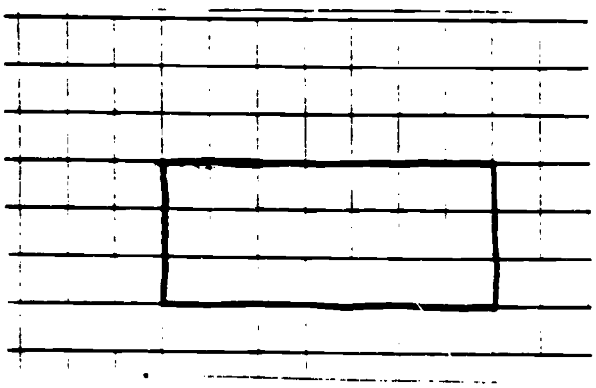
What did you think about as you answered the question?

What other ways could you have gotten an answer?

Posttest

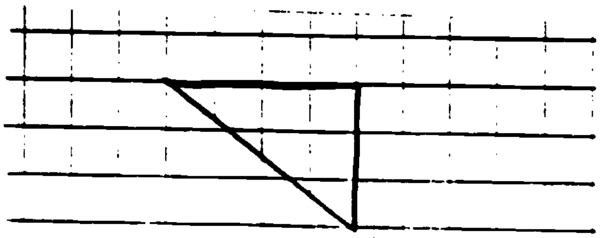
I. Key Math subtests, Measurement and Problem Solving

II. Questions with a Geoboard:

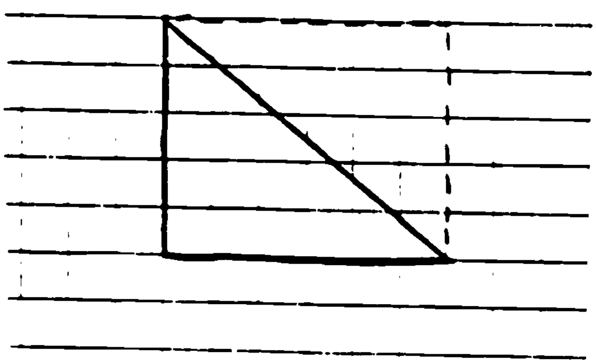


I used 21 units to cover this shape.

(Cover a rectangle with 21 units.)



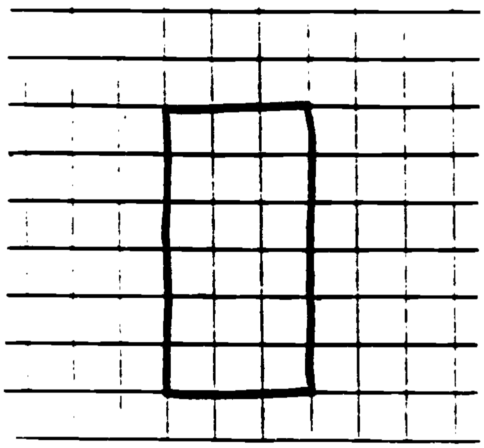
How many units would it take to cover this shape?



What did you think about as you answered the question?

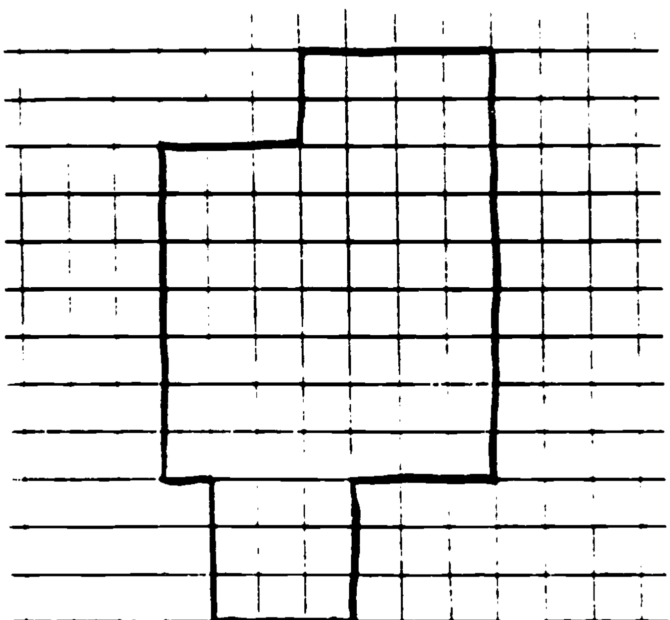
What other ways could you have gotten an answer?

III. Questions with Graph paper:



I used 18 units to cover this shape.

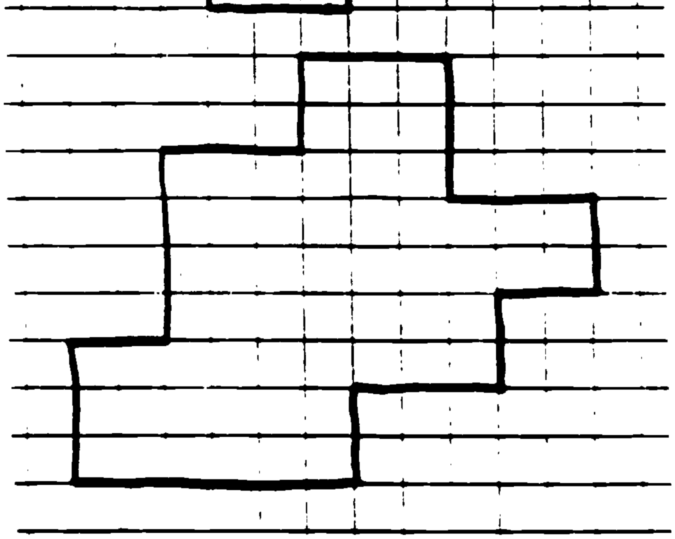
(Cover a rectangle with 18 units.)



How many units would it take to cover this shape?

What did you think about as you answered the question?

What other ways could you have gotten an answer?



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