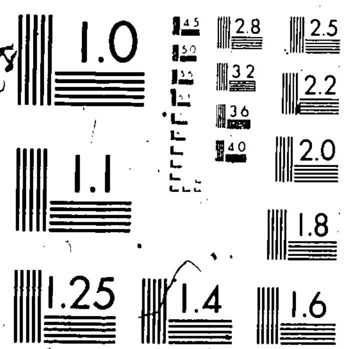

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ABSTRACT

As part of the Mathematical Problem Solving Project, MPSP, the goals and purposes of miniprojects are explored. Various conjectures are presented which are based partially upon observation of children working on projects and partially upon the opinions of mathematicians who have observed how problem-solving processes are used in real-world situations. Four miniprojects are outlined and a report on one project is given. (MP)

MATHEMATICAL PROBLEM SOLVING PROJECT

MPSP

A Project of the
MATHEMATICS EDUCATION DEVELOPMENT CENTER

Project Supported by
National Science Foundation Grant PES74-15045

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FINAL REPORT
MATHEMATICAL PROBLEM SOLVING PROJECT

TECHNICAL REPORT VIII:

MINIPROJECTS
(A MATHEMATICAL PROBE)

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MATHEMATICS EDUCATION DEVELOPMENT CENTER
Indiana University - Bloomington
May 1977

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TECHNICAL REPORT VIII.
MINIPROJECTS
(A Mathematical Probe)

I. Goals and Purposes of the Miniprojects

"An average size tree will produce about 25 kilograms of paper. Estimate how many trees must be cut down to produce all the paper used by your school in one year."

This is an example of a miniproject which is designed to give elementary school children experience in working in real-world situations which can be understood better with the use of mathematical methods and reasoning. These situations or problems may arise from the students' own experiences or surroundings or may come from some current news item or some recent scientific or social development.

To put the miniprojects and applied problems into perspective, it may be appropriate to discuss the different types of problems to which children may be exposed. (1) Textbook exercises; e.g. $\begin{array}{r} 329 \\ \underline{+\ 35} \end{array}$ These exercises appear in textbooks in order to develop skill with algorithms. (2) Textbook word problems; e.g. Sally has 7 apples and is given 3 more. How many apples does she then have? These problems are used to motivate the basic operations by tying them to familiar situations. They also tend to develop skill with the basic facts or algorithms. (3) Puzzle problems; e.g. If 5 people are going to shake each other's hands, how many handshakes will result? These problems are selected to emphasize certain problem-solving processes or strategies. They have been used extensively in the MPSP modules, problem decks, and GASP problem boards. (4) Applied problems, e.g. When will the same calendar as that of 1977 again be correct? That is, when will the days of the month next match those of 1977? These problems relate directly to real-world situations and are often open-ended, leading to further investigations.

(5) Miniprojects; e.g. The paper conservation project given above. It is the aim of the miniprojects to give children an opportunity to go through all of the steps involved in mathematical modelling, or in other words, in the scientific process, in situations in which mathematics naturally arises. This means that the students will see a situation and formulate a problem. They decide upon the methods to use to solve it, collect the necessary data, do the required calculations, and finally interpret their results. The problems one encounters throughout life often require these steps for their solution, but the usual textbook problems do not develop the students' ability to handle such problem situations. The usual textbook problems and exercises generally require the student merely to apply just the method under discussion and does not train the student to go through the scientific processes described above. When the student later encounters a problem situation, he/she often feels that the school training in mathematics was not adequate. In short, he/she has not learned how to really apply mathematics in the kinds of situations similar processwise to those one is likely to encounter later in life.

The paper conservation problem presented above was given to a team of six fifth-grade children at Arlington Elementary School in Bloomington, Indiana. They worked together to solve the problem for seven half-hour sessions. In general, the miniprojects are designed to take from two to six hours, extending over several days or weeks. The children spent the first few sessions understanding the problem and simplifying it into manageable tasks such as first finding out how much paper is used in a day or a week. They then generated a list of kinds of paper used in the school and the ways in which they are used. Each child selected a place to go for data (classroom, office, kitchen, custodian, etc.) and spent one session getting the desired information. After collecting the data, the children returned to calculate the total amount of paper used in the school, making use of electronic hand calculators. The group then discussed the implications of their results with the teacher.

In the remainder of this section, various conjectures will be presented which are based partially upon observation of children working on the project and partially upon the opinions of mathematicians who have observed how problem-solving processes are used in real-world situations. As mentioned above, one important purpose of these miniprojects is to give children experience in formulating the mathematical problems they must solve from the situations they are presented. This is quite a different experience from solving mathematical problems given to them directly. They should gain experience (ways of thinking) that could later help them see how to introduce mathematics into other situations which they try to analyze.

The miniprojects, such as the one described above, involve the use of mathematical concepts and skills that the children have already studied. The miniprojects are not meant to teach new mathematical content but to reinforce previously learned skills by having to apply them in different and practical situations. From our observations of children working on a project, we have seen that they sometimes have data but can not decide which of the four basic operations (addition, multiplication, subtraction, or division) must be used to get what they are looking for. The usual classroom instruction in the basic skills develops their technique through drill but it does not give them a working knowledge of when a given operation must be used in a practical situation. This practical context is provided in the miniprojects in which the child has certain data and must decide which mathematical operation must be used to get the information he/she wants from the data. It can be conjectured that if this ability to decide what mathematical operation is appropriate in getting the desired information from data were developed from the early grades on, people would have much less trouble applying their mathematics in the situations they encounter later in life.

In the paper conservation miniproject, as in many of the others, the data is not given to the children but must be gathered by them. This means that they have to plan what data they need, what or who are the sources of the data, and what questions they should ask to get the data. Our observations of children indicate that they often had not had enough experience organizing the information they generated or collected to enable them to work efficiently. (Modules have been prepared in the MPSP to develop skills in organizing lists and making tables, so this deficiency will be partially overcome for the children who use those modules before doing the miniprojects.) Doing these miniprojects gives the children practical experiences in which the organization of information is necessary and this important problem-solving skill is both motivated and reinforced through these miniprojects.

Another topic that working applied problems naturally leads to is working with measurements, and these measurements have certain units associated with them. (These may be metric or British units, whichever the teacher prefers.) The units are an essential part of the problems, and the students should be encouraged to keep these units in mind as they do their calculations. In some cases, it is necessary for the student to convert from one unit to another, for example, from inches to feet or from dozens to individuals. Children seem to have difficulty with such conversions, so that an awareness of the necessity of such conversions and some practice in doing some (perhaps with some guidance at first) are further benefits that children may derive from these mini-projects.

Even though the children may be working on one part of the project at a given time, it is important that they understand the goals of the whole project and how the part they are doing fits into the whole. They should be aware that they must take stock of where they are, to see if their calculations make sense and are leading to something useful. At the end, they should be able to tell whether the results they have found actually solve the problem they set out to solve. This means interpreting their results, for in many such projects, there is no single correct answer which is known by the teacher in advance. For example, the outcome of the paper conservation problem depends upon the school and many other factors. The important thing for the teacher and the students to realize is that they are looking for a <u>reasonable</u> estimate.

The miniprojects are in general designed to be done in or around the school so that they do not require elaborate field trips or disruptions. The data that cannot be collected easily at school will be provided with the problem. In some instances, it may be necessary to get some information about the local community which can be obtained at home and brought to school the next day. In some cases, the children can use their own estimates for some of the data that is needed. Making sensible estimates is another useful skill that can be reinforced by such projects where they arise naturally. In some of the projects, the calculations involve large numbers. Here is a good place for the electronic hand calculators to play a natural role; for it is in situations like these that the students will use calculators later in life. The calculators also enable the students to get on to the solution of their project much faster without getting bogged down in tedious calculations. Estimating and rounding-off are useful skills that can often be used when calculating with large numbers. (These are skills which are developed in the module, "Using Guesses to Solve Problems" and these mini-projects offer positive reinforcement to the previous instruction. The students see when these skills are useful in a problem that arises naturally in their work.) Watching the children use their mathematical skills in these projects affords an opportunity for the teacher to see whether some of the children are having difficulty using some of the things they had previously been taught. The teacher can also see whether the children can transfer their knowledge of the basic skills to a practical situation and help them in this important aspect of understanding mathematics if they are having difficulty.

We have found that students in general (1) do like challenging problems, and (2) do experience elation at achieving their goals. We believe that the teacher should direct the activities of the students in such a way as to give a feeling of ownership of the project to the students. It is really their project and not the teacher's. It is important that the teacher not give answers but only help with appropriate hints. Once again, these hints must be carefully thought out so as not to spoil the problem. As one person put it: "Hint" is a four letter word.

As pointed out earlier, the miniprojects are designed to take from two to six hours to complete, significantly longer than the usual mathematics textbook problem. As such, the miniprojects give the students an opportunity to stick with a problem for an extended time until some form of closure is reached. On a small scale, it serves some of the same purposes as the more extensive projects designed by USMES. Those projects also present the students with realistic situations in which mathematics enters naturally. Those projects are meant to last much longer, even up to a whole semester. These miniprojects are much shorter so that they can be inserted into the regular curriculum whenever the teacher wishes. Mathematics enters into the miniprojects in many ways and in guises that students often do not recognize as mathematics, but which the professional mathematician believes to be important ways of using mathematical reasoning. The miniprojects should broaden the students' and perhaps even the teacher's perception of mathematics and its usefulness and may improve the attitudes of some of the students towards learning mathematics.

The classroom management question can be dealt with in different ways for different projects and for different teachers, according to the teacher's preference. In some cases, an individual may want to work on a project alone, whereas in some cases, small groups of two, four, or six students may cooperate in working on the same miniproject. A larger group working on a project may want to divide up into task forces assigned to different aspects of the problem or to collecting different data. In some cases, the teacher may want the whole class to work on the same project. Many of the miniprojects are open-ended, leaving several options open to the students to follow up after they reach their original goal or even as branches along the way. This kind of further exploration is to be encouraged in so far as possible, considering other time constraints. Some students may want to explore further into one of these problems on their own time after the class

has finished it. These miniprojects can be a very rich and rewarding experience for the students.

In summary, these miniprojects are meant to meet the following needs:

1. [illegible] offer the students an opportunity to use their mathematical s[illegible]uations which are similar to real-world problems. They show [illegible] [illegible]athematics is useful.

2. They are designed to give the students introductory experiences in elementary mathematical modelling, i.e., using the scientific method to handle real-world problems.

3. Many of the projects give the students experiences in collecting, handling, and interpreting data; they provide experiences in organizing information.

4. The projects give the students practice using measurements or numbers with units in a natural setting. Their calculations often involve estimating and rounding off. The children must decide which operations must be used to achieve a desired goal.

5. The miniprojects provide an opportunity for the students to engage in an activity which is similar in character to applications of mathematics that one encounters in later life. It teaches them how to handle such situations independently and should enable them to use their mathematics more effectively as adults.

6. Many of the projects give the children practice in taking a large problem, breaking it down into smaller problems, and setting subgoals with the aim of progressing towards the final goal.

II. <u>Several of the Miniprojects</u>

A. *Paper Conservation Project*

Trees are a very valuable natural resource in our country. They help prevent flooding and soil erosion. Each year many forests are cut down to provide paper and wood products for the people in the United States. Americans use many more paper products than do people in other countries, and there is a danger of depleting one of our most beautiful and important resources. Have you ever wondered how much paper your school used in a year and how many trees are cut down to produce this. [illegible] estimate how [illegible] takes to produce the paper used in your school in a year.

DATA: One tree will produce about 25 kilograms (50 pounds) of paper.

SUGGESTIONS (If Needed):

1. List the different types of paper used by your class and the amounts used per day, per week, and per year.
2. Where else is paper used in your school? Again list the types and amounts of each type used.

SOME EXAMPLES: Art paper, wrapping paper, paper cups, paper towels, cardboard cartons, etc.

3. Estimate how much each kind of paper weighs. Then estimate the total weight of the paper used.
4. How many trees will it take to supply the paper used in your school?

ADDITIONAL QUESTIONS:

1. How many acres of forest are needed to produce the year's supply of paper for your school? How many football fields would this cover?
2. Suppose your school wants to buy some land for planting trees so that the school can always get all its paper from its own trees. How many acres should they buy to be sure of having enough trees each year? To save money, they do not want to buy more land than is necessary.

B. *Optical Fiber Telephone Lines*

A recent development is the use of lasar beams sent through optical fibers to carry telephone messages. This is much more efficient than the usual copper wire cables that have been used for years. The optical fiber cables are being tried in Chicago for use within the city. The next step will be to connect several of the major cities with optical fiber cables. Suppose that the telephone company has selected the following eight cities to be connected by optical fiber cables: Chicago, Detroit, Houston, Los Angeles, Miami, New York, Philadelphia, and Seattle. Because the cable is expensive to install, they would like to join the cities with as short a path as possible, so that a call can be placed from any one city to any other, possibly having to pass through some of the other cities first. Find the shortest path joining the eight cities.

DATA:

	Chicago	Dallas	Detroit	Houston	Los Angeles	Miami	New York	Philadelphia	Seattle	Washington
Chicago										
Dallas	917									
Detroit	226	1143								
Houston	1067	243	1265							
Los Angeles	2054	1387	2311	1538						
Miami	1329	1300	1352	1190	2687					
New York	802	1552	637	1608	2786					
Philadelphia	738	1452	573	1506	2706	1208	100			
Seattle	2013	2078	2279	2274	1131	3273	2815	2751		
Washington	671	1319	506	1375	2631	1075	233	133	2684	

SUGGESTIONS (If Needed):

1. Try doing a similar problem with three or four of the cities, perhaps taking them close together.
2. It may be fun to divide the class into several teams and have the teams compete to see which team can find the shortest path joining the eight.
3. See if someone can devise a procedure that leads to the shortest path, other than trying lots of possibilities to see which is the shortest.

ADDITIONAL PROBLEM:

1. What is the shortest path joining New York, Philadelphia, Miami, and Detroit? Can you make the path shorter by finding a new city through which you can join some of these cities? Try to do the same thing with Chicago, Houston, Los Angeles, and Seattle.
2. In the above problem, try Washington, D.C. in the east and Dallas in the west.
3. Now using the ten cities (adding Washington, D.C. and Dallas to the original eight) find the shortest path joining all ten cities. How does this compare to the original shortest path through the eight cities?

C. *Plan a School Building*

Suppose that your community wishes to build a new elementary school for 300 children. They wish to put in all the rooms to make it a pleasant modern school with everything you think a school should have. They also have to keep the cost as low as possible so that taxes will not have to be raised. Make a plan (drawing) of the school building showing all of the rooms and hallways and show the measurements of each part of the building. Estimate how much it would cost to build the school.

DATA: Building costs are now about $60.00 per square foot.

SUGGESTIONS (If Needed):

1. In this project, the class can be divided into teams of four or six students each and have each team work on its own plan. Then compare the costs and plans to see who came up with the best design taking into account the facilities available and the cost. This could lead to interesting discussions between the teams, showing that such matters are often subjective and that there may not be a single correct answer to every problem.
2. These are things the teams can consider in making their designs:
   (a) How many grades are in the school?
   (b) How many children are in each grade?
   (c) How many children should there be in each classroom?
   (d) How big should the classrooms be?
   (e) Should there be a cafeteria, an auditorium, a gymnasium? Can any of these rooms be combined?
   (f) What other rooms are necessary? An office, a nurse's room, a teacher's lounge, a kitchen, a furnace room, restrooms, library, etc. Any others?
   (g) How wide should the halls be?

ADDITIONAL PROBLEMS:

1. Plan the playground and parking lot around the school.
2. If floor tiles are one foot square (12 inches on each side) and a box contains 45 tiles, how many boxes of tile will be needed to cover the floors of the school? Each box of tiles costs about $40.00. Estimate the cost of the flooring.

3. A gallon of latex paint covers about 450 square feet. Estimate how many gallon cans of paint are needed to paint the inside walls, and the ceiling of the school. If a gallon of paint costs $10.00, est[illegible] painting the interior of the school.

D. *Water Tank Problem*

A new water tank is going to be built in the shape of a cube to serve your community (the area in which the children come to your school). It is to be big enough to hold enough water to supply the needs of the community in a typical 24-hour period during the summer. Estimate how much water is used in your community during that time and how large the tank must be, to hold that much water.

DATA: 1 cubic foot is about $7\frac{1}{2}$ gallons.

SUGGESTIONS (If Needed):

1. List the different ways in which water is used in your community.
2. Estimate how many families are in your community.
3. Which businesses or industries in your community use water?
4. How much is used in public facilities such as swimming pools, schools, parks, etc.?

ADDITIONAL PROBLEMS:

1. Estimate the amount of water used in your home in a typical summer day (24 hours).
2. If you can find [illegible] cost of water in your city, estimate the cost of the water used in your home in one day.

E. Healthy Diet

The U.S. Department of Agriculture and the National Academy of Science have published tables which show the nutritional values of the foods we eat and another table which tells us the amount of each nutrient we need each day for a healthy di[illegible] are incl[illegible] on pages 15 [illegible] family of four people (father, mother, son, and daughter) for a week. In order to keep one's weight under control, one wants to keep the amount of calories low, but to stay healthy, one should be sure to have at least the minimum amount of each of the other nutrients. Thus, see if you can plan the meals for a week so as to have at least the minimum daily requirements for each of the vitamins, minerals, and proteins, but to have the smallest amount of calories.

SUGGESTIONS (If Needed):

1. One can have several teams working on diets and see which comes up with the most attractive menus which meet the nutritional needs and have the least calories.

ADDITIONAL ACTIVITIES:

1. It would add to the problem if the actual tables of nutrients in foods and the minimum daily requirements could be found in the library and used in the project. More foods could be added and other nutrients such as carbohydrates, fiber, fats, etc. could be considered. The group could decide what amounts of these are desirable in the diet and plan meals accordingly.
2. By consulting newspaper ads placed by supermarkets or by accompanying parents while shopping, the students could get costs of the basic foods on the list and see how much the food for the week would cost. Minimizing cost while meeting nutritional needs is another good problem (which was actually solved for the first time in the late 1940's).

RECOMMENDED DAILY DIETARY ALLOWANCES

	Age (years) From	Age (years) To	Weight (pounds)	Height (inches)	Calories	Protein (grams)	Calcium (mg)	Iron (mg)	Vitamins A (units)	B_1 (mg)	B_2 (mg)	Niacin (mg)	C (mg)
Men	18	35	154	69	2900	70	800	10	5000	1.2	1.7	19	70
	35	55	154	69	2600	70	800	10	5000	1.0	1.6	17	70
	55	75	154	69	2200	70	800	10	5000	0.9	1.3	15	70
Women	18	35	128	64	2100	58	800	15	5000	0.8	1.3	14	70
	35	55	128	64	1900	58	800	15	5000	0.8	1.2	13	70
	55	75	128	64	1600	58	800	10	5000	0.8	1.2	13	70
Children	1	3	29	34	1300	32	800	8	2000	0.5	0.8	9	40
	3	6	40	42	1600	40	800	10	2500	0.6	1.0	11	50
	6	9	53	49	2100	52	800	12	3500	0.8	1.3	14	60
Boys	9	12	72	55	2400	60	1100	15	4500	1.0	1.4	16	70
	12	15	98	61	3000	75	1400	15	5000	1.2	1.8	20	80
	15	18	134	68	3400	85	1400	15	5000	1.4	2.0	22	80
Girls	9	12	72	55	2200	55	1100	15	4500	0.9	1.3	15	80
	12	15	103	62	2500	62	1300	15	5000	1.0	1.5	17	80
	15	18	117	64	2300	58	1300	15	5000	0.9	1.3	15	70

TABLE OF FOOD COMPOSITION

Food	Amount	Calories	Protein (grams)	Calcium (mg)	Iron (mg)	A (units)	B_1 (mg)	B_2 (mg)	Niacin (mg)	C (mg)
Desserts										
Chocolate Cake	1 slice	420	5	118	0.5	140	0.0	0.[illegible]	0.3	0.0
Gingerbread	1 piece	180	2	63	1.4	50	0.0	0.0	0.6	0.0
Apple Pie	1 slice	330	3	9	0.5	220	0.0	0.0	0.3	1.0
Cherry Pie	1 slice	340	3	14	0.5	520	0.0	0.0	0.3	2.0
Pumpkin Pie	1 slice	265	5	70	1.0	2,480	0.0	0.1	0.4	8.0
Nut Products										
Peanut Butter	1/3 cup	300	12	29	0.9	0	0.3	0.1	6.2	0.0
Beverages										
Cola	12 ounces	137	0	0	0.0	0	0.0	0.0	0.0	0.0
Fruit-flavored soda	12 ounces	161	0	0	0.0	0	0.0	0.0	0.0	0.0
Root Beer	12 ounces	140	0	0	0.0	0	0.0	0.0	0.0	0.0
Dairy Products										
Whole Milk	1 quart	660	32	1,140	0.4	1,560	0.32	1.7	0.8	6.0
Skim Milk	1 quart	360	36	1,192	0.4	0	0.4	1.7	0.8	6.0
Ice Cream	1 cup	300	6	175	0.1	740	0.1	0.3	0.1	0.0
Cottage Cheese	1 cup	240	30	207	0.9	430	0.1	0.6	0.2	0.0
Swiss Cheese	1 ounce	105	7	270	0.2	320	0.0	0.1	0.0	0.0
Fried Eggs	2	220	13	60	2.2	1,200	0.0	0.4	0.0	0.0
Butter	1 tablespoon	100	0	3	0.0	460	0.0	0.1	0.0	0.0
Margarine	1 tablespoon	100	0	3	0.0	460	0.0	0.0	0.0	0.0
Meat, Poultry										
Bacon	2 slices	95	4	2	0.5	0	0.0	0.0	0.8	0.0
Ground Beef	3 ounces	245	21	9	2.7	30	0.0	0.0	5.1	0.0
Sirloin Steak	3 ounces	330	20	8	2.5	50	0.0	0.0	4.0	0.0
Fried Chicken	3 ounces	245	25	13	1.8	200	0.0	0.1	5.0	0.0
Ham	2 ounces	165	8	5	1.2	0	0.2	0.1	1.8	0.0
Bologna	2 slices	124	7	4	1.2	0	0.0	0.0	1.3	0.0
Frankfurter	2	246	14	6	1.2	0	0.1	0.2	2.5	0.0

TABLE OF FOOD COMPOSITION

Food	Amount	Calories	Protein (grams)	Calcium (mg)	Iron (mg)	A (units)	B_1 (mg)	B_2 (mg)	Niacin (mg)	C (mg)
Vegetables										
Carrots	1 cup	45	1	38	0.9	18,130	0.0	0.0	0.7	6
Corn	1 cup	170	5	10	1.3	520	0.0	0.1	2.4	14
Cucumber	6 slices	6	0	5	0.1	0	0.0	0.0	0.1	4
Lettuce	¼ head	13	0	20	0.5	300	0.0	0.0	0.3	6
Mashed Potatoes	1 cup	230	4	45	1.0	470	0.2	0.1	1.6	16
French Fries	10 pieces	155	1	9	0.7	0	0.0	0.0	1.8	8
Tomatoes	1	30	1	16	0.9	2,600	0.0	0.0	0.8	35
Fruits										
Apples	1	70	0	8	0.4	50	0.0	0.0	0.0	3
Bananas	1	85	1	8	0.7	190	0.0	0.0	0.7	10
Oranges	1	60	2	50	0.5	240	0.1	0.0	0.3	75
Peaches	1	35	1	9	0.5	1,320	0.0	0.0	1.0	7
Pears	1	100	1	13	0.5	30	0.0	0.0	0.2	7
Pineapple	1 slice	95	0	26	0.7	100	0.1	0.0	0.2	11
Breads, Cereals										
Bran Flakes	1 cup	117	3	25	2.0	0	0.1	0.1	3.4	0
Rye Bread	1 slice	55	2	17	0.4	0	0.0	0.0	0.3	0
Wheat Bread	1 slice	55	2	23	0.5	0	0.0	0.0	0.7	0
Cornflakes	1 cup	110	2	6	1.2	0	0.1	0.0	0.6	0
Graham Crackers	2	55	1	3	0.3	0	0.0	0.0	0.2	0
Oatmeal	1 cup	150	5	21	1.7	0	0.2	0.0	0.4	0
Pancakes	4	250	7	249	1.2	230	0.1	0.2	0.7	0
Spaghetti, with meat sauce	1 cup	285	13	25	2.0	690	0.0	0.1	2.1	13
Soups										
Noodle	1 cup	115	6	82	0.2	3[illegible]	0.0	0.0	0.7	0
Tomato	1 cup	175	6	167	0.7	1,2[illegible]	0.0	0.2	1.2	0
Vegetable	1 cup	80	4	32	0.8	2,[illegible]	0.0	0.0	1.0	8
Fish, Seafood										
Fish Sticks	5	200	19	12	0.4	0	0.0	0.0	1.6	0
Haddock	3 ounces	135	16	11	0.7	0	0.0	0.0	2.6	0
Tuna	3 ounces	170	25	7	1.2	70	0.0	0.1	10.9	0

III. Classroom Probe of the Miniprojects

The paper conservation miniproject was tried on a group of six fifth-grade children in Arlington Elementary School in Bloomington, Indiana between October 28 and November 20. The teachers working with the children were Arthur Stengel and Marilyn Jacobson. In most of the classroom meetings Arthur Stengel was in charge and Marilyn Jacobson and various other visitors were observers. A class by class description of the trials is given in Appendix A. Section I of the appendix is a chronology which gives the dates on which the class met. The observers present with the teacher are underlined. The initials given there stand for Marilyn Hall (MH), Arthur Stengel (AS), George Springer (GS), Debbie Whitehurst (DW), and Maynard Thompson (MT). Section II of the appendix gives the observations of the teacher and some of the observers at each of the sessions. Section III of the appendix is an analysis of the observations prepared by Arthur Stengel and Marilyn Hall.

The classroom teacher selected more or less randomly six children to work with Marilyn Hall and Art Stengel in this project. They were excused from class for thirty minutes twice each week. For the first two sessions AS and MH met with the children to get them acquainted with the use of hand calculators and also used to working problems together. On October 22 they experimented with the use of the electronic hand calculators. On October 27 they worked on a problem of placing 9 marbles in 5 cups so that each cup had a different number of marbles. After these two warm up sessions the children were introduced to the miniproject. The teacher, AS, tried to draw a careful balance between letting them work completely alone and giving them some leadership whenever he felt that it was absolutely necessary. It should be pointed

out that these children had been working in a traditional classroom where they had had no experience in working in small groups. This was a new experience for the children.

One thing that was clear from observing the children was that they did not have experience and were not able to organize either a long series of tasks or a large amount of information. With the teacher's help they made lists of different types of paper used in the school. By the third half-hour session the children were deciding what data each one would try to collect in the school. They also worked out the questions they would ask while seeking the information. In the fourth session the children actually went out either individually or in groups of two to ask different people at the school how much paper was used in their operation. Some went to classrooms, some to the kitchen, some to the main office. After gathering the data the children sat with calculators to figure out the total amount that was used. It was at this point that it became clear that the children did not know how to apply in a practical situation some of the arithmetic skills which they could use quite well in drill problems. It wasn't clear to them when they had to multiply or divide, or when they had to add or subtract, even though they could perform these operations quite well. Getting through this phase of the project required the assistance of the teacher in explaining to the children just why the operation they needed was appropriate at that time and in interpreting the numbers on the display. In the last meeting on November 20 the calculations were completed and there was a discussion of what the results actually meant. It would have taken about two more half-hour sessions to bring the project to the completion we had originally planned; that is, estimating the weight of the paper used and the number of trees necessary to produce that much paper. It was unfortunate that the Thanksgiving holiday came just after the November session and there would have been a week break before resuming the trials. It was decided that that was too long a break and that we would stop at that point. It would have been interesting to see how they would have weighed the paper and decided on the number of trees. However, the children were very pleased with their accomplishments in finding the amount of paper actually used in the school, and felt that this was an important contribution.

There were several things the children derived from working on this miniproject. First of all, they did see that the mathematics they had been learning can be used in practical situations. They became aware of the fact that they have to consider what operation is appropriate to achieve the goals they had set for themselves. They also became aware that it is necessary to organize their information in lists in order to be able to work with it. They had the valuable experience of sitting together in a small group and planning how they would solve the problem. They saw how a complicated problem can be broken up into a series of tasks which can be assigned to different individuals. It would have been interesting to give these children several more of the projects in sequence and see to what extent these skills had been learned and could be transferred to another project. Another observation is that it would have been preferable to give the project in a more concentrated period of time. Meeting only twice a week for a half hour each time and extending the project through three and a half to four weeks made it difficult to keep the children at a high level of excitement about it. We always had to get them back into the problem at each session by helping them remember where they had left off. It would have been better to have spent time during one week on this project. As it was, the children were involved for three and a half hours, which could easily have been fit into one week's work. Even though the project did extend for such a long period of time and with such gaps in between meetings, there was no significant decrease in the interest shown by the students once they remembered where they were in the project. It seems as though there was no problem of fifth graders sustaining their interest in a problem for this much time. We feel that there is much room for experimentation on this type of project to see whether after repeated experiences of this type the children are able to handle these situations better independently. It is hoped that such experimentation will be carried out in the future.

IV. Applied Problems

In addition to the miniprojects described in the previous sections, the project also generated a number of applied problems. These problems are meant to give the students the same general type of open-ended experience in problem solving that one finds in the miniprojects but in situations which are less complex. As do most of the miniprojects, they relate in some way to real-world experiences. A sample of these problems is given below. They were provided by Maynard Thompson.

Problem 1

Mr. Jones has a leaky pipe under his kitchen sink. He normally keeps a portion of a one-half gallon cardboard milk carton under the sink to catch the water which drips from the pipe. He cut a carton 4 inches from the base and he found that it filled in 3 days. He plans to take a 16-day vacation and he has a one-gallon cardboard milk carton from which to make a container to catch the water. How high must he cut the carton to be certain that it will not overflow while he is gone?

Problem 2

If a runner has a time of 4 minutes and 56.0 seconds in a mile run, estimate as accurately as possible his time in a "metric mile," that is, the 1500 meter run. What do you need to take into account in making your estimate?

Problem 3

When will the same calendar as that of 1975 again be correct? That is, when will the days of the month next match those of 1975?

Problem 4

Once during the Christmas season a family was seated around the fire drinking hot chocolate. David noticed that each of them had a cup decorated with a different holiday scene. He had a cup showing bells, his sister had one showing candles, his mother had one with a wreath and his dad had a cup decorated with carolers. The next night they were again drinking hot chocolate, and David noticed that none of them had the same cup as the night before. In how many ways could this happen?

Problem 5

A storekeeper has a supply of 5¢ and 8¢ stamps. What amounts of postage can he place on packages using these stamps? He may use as many 5¢ stamps and as many 8¢ stamps as he pleases.

Problem 6

A confidence artist has a rectangular bar of lead which measures 1 cm x 3 cm x 10 cm. He plans to plate the bar with gold and pass it off as a gold bar. If he has only $50 to buy gold to plate the bar, how thick will the plating be? By how much will the weight of the plated bar differ from the weight of a pure gold bar of the same size?

APPENDIX A

REPORT ON PROBE OF MINI-PROJECT TREE CONSERVATION PROBLEM

October 28 - November 20, 1975

PREFACE

This report represents an attempt by Marilyn Hall and Arthur Stengel to pull together and summarize information gathered during the probe of the Mini-Project Tree Conservation Problem. The pages which follow are divided into three main sections. They include: Chronology, Observations, and Analysis.

While every attempt was made to represent the views of all participants in the probe, the report must, to some degree, be biased by the authors' views. The Analysis section was created by the authors to facilitate discussion of the probe. It should not be assumed that any issue raised or position taken represents anything more than a starting point for further efforts.

SECTION I

CHRONOLOGY

Mini Project

Chronology

Session Date	Observers	Session Content
October 22 and 27	MH AS	Warm-up with: 22: Calculators 27: Worked cups/marbles
October 28	MH AS GS DW MT	Problem presented → open discussion → teacher-led discussion/listing of specific kinds of paper
October 30	GS AS	Teacher-led discussion on (consumable nature of paper use) and organizing specific kinds of paper by general types. This led, in turn, to listing kinds of paper used by types of rooms.
November 4	MH AS	Assigned children to rooms and let them devise questions to ask on paper use.
November 6	MH AS GS	Kids went out and gathered information.
November 13	MH AS GS	Some children initially continued gathering information with data gathered. All did some calculations with the data.
November 18	MH AS DW	Discussion on what's gone on and what needs to go on. Gathering of "needed" data.
November 20	MH AS DW	"Calculations" were completed and "the final answer" was found. Summary discussion.

SECTION II

OBSERVATIONS

Observer's Name:

Marilyn Hall, Art Stengel*, George Springer, Debbie Whitehurst, Maynard Thompson

Date of Observation:

October 28

Observations:

-- Children have knowledge of where paper comes from. They were very willing to guess amounts. Unit used--pieces (sheets of paper)

-- Without adult leadership, discussion was non-directed and children were not moving toward any type of plan of action. Adult leadership intervened and was quickly accepted by children.

-- At least one child moved toward simplifying problem to semester level and then another moved toward simplifying problem to day level use; but no one knew where to go with this unit. (It seems that they couldn't deal with relationships of per day to per month to per semester to per year.

-- The children seemed to have the tendency to want to actually have the teachers keep track and add actual use each day.

-- Notion of averaging or estimating for real use is not comfortable for these children. They really wanted to get an exact count. Discussion did not really clarify this issue.

-- Children were very willing and able to come up with ideas for resources in which x paper = y trees relationship could be found. But do they have the "research" skills to find that information?

-- When presented with a problem, children were very willing to suggest ways to solve it (e.g., people to talk with and places to look). Yet several opposing ideas came up in the course of conversation that they did not seem able to reconcile on their own. Teacher intervention did lead to at least a facade of resolution; but whether this actually settled an issue for a child remains questionable.

* Indicates session leader

Observer's Name:

George Springer, Art Stengel*

Date of Observation:

October 30

Observations:

-- Idea of consumable nature of the paper in question was established by teacher's fiat without real notice.

-- Question was posed to group by teacher on types of paper used in school (this was, indeed, a false path to follow). Children were willing and able to generate a large list of specific types of paper used. The specifics were by use not by types of paper. I.e., one type of paper was mentioned several times because it was used in the school several ways. This created confusion and, to some extent, the relationship of types and uses was not resolved.

-- The listing of types of paper was a long and arduous process. It generated a lot of discussion. When teacher would withdraw, debate disintegrated into argument with children showing no signs of ability to resolve the disagreement.

-- The value of doing this listing seems questionable: 1) the children's ability to organize their thinking along the lines of types of paper seems marginal. This seems directly related to finding of Marilyn, Frank, and Art re: organized lists. Multiple factor listing with several items under each factor was beyond the grasp of the other kids. This seems to verify that finding. 2) Even if the children got a complete and well-organized list, what good will this do when they go out and generate data? If the intention is to use the list in developing questions to ask, it seems to be an awfully roundabout way of doing it.

-- The list of "kinds of paper" remained far from all-encompassing. How important is a thorough list?

-- Issue of consumable nature of paper in this problem remained unclear to kids. What products were eligible for consideration in the problem was brought up several times.

* Indicates session leader

Observer's Name:

Marilyn Hall, Art Stengel*

Date of Observation:

November 4

Observations:

-- Process was re-directed: from teacher-centered listing of kinds of paper to student-centered formulating of list of rooms that use paper and questions to ask folks in those rooms. Students accepted this re-direction unhesitatingly and proceeded to suggest rooms, etc. List of rooms and questions to be asked were not complete or thorough.

-- Much non-task activity took place during the student-centered question formulation time. Teacher questioning as to whether task-oriented activity was taking place was not really effective in achieving task orientation.

-- One issue seems to be the general one of leadership within a group process. In any group of people, will the group stay on task and/or achieve closure on an idea (or task) without a leader? In this type of problem, if the teacher doesn't lead, who will?

-- Is it reasonable to expect students from traditional classrooms to just function in groups without specific (direct) instruction or (indirect) assistance from the materials?

-- The listing of types of papers, etc. did not enter into this question formulation stage.

* Indicates session leader

Observer's Name:

Marilyn Hall, Art Stengel*, George Springer

Date of Observation:

November 6

Observations:

-- The notion of average, how to get average use, or how to estimate overall paper use still seems up in the air.

-- Children were excited about going out to ask questions and got their lists together very quickly (in contrast to last Tuesday's session). This activity was without adult direction. Also, no teacher suggestions were provided and nature/value of questions seemed dubious.

-- Some questions did not seem to bear on issue: What colors do you use? One wonders whether the kids really knew what they were about. Also, do good questions matter?

-- Gary & Blair came back with data on paper use in the kitchen: 1) The data was somewhat difficult to understand (for the adults especially); 2) The boys did not really know what to do with it:

They tried to work	10,000	napkins/case
	x 300	packs of napkins/case
	1	?

Teacher involvement at this point was solely to explore the boys' thoughts.

-- Among issues here: 1) Is accurate data important? 2) Taking at face value what the children bring back, they are not able to do the needed calculations with that data. This may mean two things (though the two could actually telescope into one: 1) How to organize the data so that calculations can be done was not clear to them; 2) The actual algorithms needed were also beyond them.

* Indicates session leader

Observer's Name:

Marilyn Hall, Art Stengel*, George Springer

Date of Observation:

November 13

Observations:

-- With the calculators, the children went about doing the same calculations as without them. Again, at this point, adults were involved only to try to understand the thought processes being used. Two issues can be raised: 1) The decision of what to do with the data is still not a logically clear one for the children. 2) The calculator display was either accepted without question or checked by hand, raising the question of whether or not the machine is of any real value. Generally, the children wanted to divide or multiply; but no one was sure why. (Or what the "answers" they got meant.)

-- One child could not get data on the room she chose. What are the implications of this for that child vis-à-vis the group?

-- One child did decide to work with 350 packages/year when given a figure of 300-400 packages/year. (Yet, then she divided by 500 (because there are 500 sheets/package?).)

-- With help in organizing data and setting up the necessary algorithm, only some of the children caught onto what needed to be done. Even then, they didn't transfer this to another similar sub-problem.

-- Relationship of how many per pack, then packs per case and then cases per year and relationship of school days/week, weeks per school year and school year to calendar year seemed difficult for the children to keep straight.

-- Remainders in decimal form were not within the children's repertoire: "What a high number. And all I wanted to know was 25 divided by 7."

* Indicates session leader

Observer's Name:

Marilyn Hall*, Art Stengel, Debbie Whitehurst

Date of Observation:

November 18

Observations:

-- Making estimate from a sample is still tough. They did get into it when pressed (Gary:"It's sort of like a maybe."); but always seemed to bounce back and forth between estimating and wanting concrete figures (actual uses). (Susan: most into estimating; Andrea: most into actual use)

-- What data represents is not clear to them: e.g., paper towels figure, ditto paper figure. Who is giving what figures on whose use is not understood by kids.

-- What types of paper are being considered is still not clear: do workbooks count?

-- Blair had a good notion of what to do with lists of types of paper-- use it as a checklist against information gathered. But, no one else picked up on it, then he, too, dropped it without a hassle.

-- Gary & Blair were convinced that all they had to do was add all the different numbers gained to get the answer. Towels, napkins, etc. were judged equal.

-- In conversation, no one brought up paper use per year re: number of trees used up. Focus was on amounts of paper as per data gathered.

* Indicates session leader

Observer's Name:

Marilyn Hall*, Art Stengel, Debbie Whitehurst

Date of Observation:

November 20

Observations:

-- This session was primarily organized and led by teacher.

-- In response to question on what needed to be done, responses like "calculate it" and "add all those together" were typical.

-- Various relationships remained unsettled: one child wanted to multiply a figure by 2 to get use for three rooms. Since her figure represented use for 1 room, she only needed 2 more! Another wanted to multiply a per year figure by 180 days (in a school year). Another child wanted to multiply number of paper towels by number of napkins. And, still another wanted to multiply 9 x 12 (because a sheet of paper is 9 inches x 12 inches?). (Her answer on the calculator was 108 and she said it was "108 inches...I mean centimeters.") "Answers" to sub-problems were the result of this type of thought and work.

-- The intensity of the children's efforts to achieve an answer was very great and impressive.

-- Reconciling data gotten from sources with personal perception of use was never accomplished. E.g., napkin use must be higher because some people rip theirs up and have to go back for more. What do the data really mean to these children?

-- Once the "grand figure" had been tabulated, one child did say that we now had to figure out how many trees. It was not clear what the others thought of this idea.

-- The children were impressed with the "grand figure." Probably because it was large. It is also probable that it was this factor--size--that led to the assumption which they stated. That is, the school was wasting a lot of paper.

-- A thought arose in watching the last couple of days: Were the children adding non-equivalent units because they are, developmentally, unable to deal with equivalence? Or are they so well trained to just add numbers that this problem became another, larger, but typical problem in which numbers exist exclusive of unit?

* Indicates session leader

-- Sample of final comments from the children:

"We found out how much paper we used and how much we shouldn't waste."

"It was fun."

"It was boring."

"We got to use the calculators."

"We got to go out and go to the classrooms."

"We got to miss a Social Studies test." (This was on the last day only.)

"I never knew we could figure it out...but we did!"

SECTION III
ANALYSIS OF OBSERVATIONS

I. Problem Feasibility for Children

A. Affective Issues

1. Interest in problem

a. Initially (first session)

1) High

b. During other session

2) Varied from day to day

2. Feelings of success

a. On parts of the problem

1) Positive feelings resulted from completing data gathering and data manipulation.

2) Otherwise, no success or failure affect noticed.

b. On whole problem

3) Yes (see cognitive issues for discussion of problem perception)

3. Activities of particular note for degree of affect generated

a. Generating questions to be asked yielded intense work just prior to going out. (Interestingly, the same task did not yield the same response at the end of the previous session.)

1) The exception was one girl who could not gather data from her chosen source. She was quite upset with this turn of events.

b. Gathering information challenged children and was especially enjoyable for them.

c. Performing calculations with gathered data and working toward the final answer had all the children working hard.

d. Questions soliciting opinions from the group generated much discussion, involvement and a good deal of argument.

B. Cognitive Issues

1. Ability to structure (accommodate) problem

a. Big (whole) problem

1) Very limited if existent at all

a) Initial discussion was enthusiastic and touched on strategies. But, without adult leadership, it remained disorganized and non-goal directed.

b) Even with adult leadership, lack of resolution of conflicting ideas makes one doubtful of students' ability to grasp the problem in its entirety.

b. Sub-problems

2) Somewhat greater, but still quite limited

c) Lack of ability to develop precise questions for data gathering and inability to grasp meaning (relationships) of data again raises doubt of the students' ability to grasp sub-problem on its own terms.

2. Ability to assimilate problem

a. Big (whole) problem

1) High

a) Enthusiasm surrounding the achievement of the "answer" indicates the existence, for the children, of a problem they have successfully dealt with. They have, it seems, modified the problem to suit their perceptions of it.

b. Sub-problems

2) High

b) See comment above on assimilation of whole problem. Situation here is analogous.

3. Goal perceptions

a. Ability to perceive goal

1) Must be severely reduced by cognitive limitations

a) Willingness to accept "a number" as the solution seems much to the point here.

b) Yet, one must keep in mind that a goal was perceived and achieved by most all of the students.

b. Ability to keep goal in mind

2) Good, if one is willing to accept student-perceived goal as actual goal

c. Perceptions of acceptable solution

3) All children were quite satisfied with simply adding up all the numbers they had gotten.

4) One child said that we then had to figure out how many trees this was. But, in later discussion, this same student stated great pleasure at having gotten the answer. It seems as though there were two separate problems in the child's mind--one to get the amount of paper and another to get the number of trees. Apparently the two were not related as one task to be done.

4. Content level

a. Many issues touched on in this problem were not readily understood by the children:

1) Relationships as described below remained unresolved issues for them.

a) School week to calendar week to school month to calendar month to school semester to school year to calendar year.

b) Various units of a given type of paper, e.g., napkins to packs of napkins to cases of napkins.

c) Various units of different paper to each other, e.g., napkins to paper towels to ditto paper.

d) Types of paper to data needed to solve problem and which way(s) of categorizing "types" is (most) helpful in gaining needed data. (e.g., does listing by color help?)

2) Using an estimate vs. getting actual use figures was never resolved. At times some of the children seemed quite set on accepting estimates only to turn around and hedge back to needing actual figures.

3) Finding a way of equating the various paper units did not really enter into their picture of this problem.

4) Calculations with the data gathered were of no value or meaning. Numbers were multiplied or divided without reason and answer had as much meaning.

C. Group Issues--While these undoubtedly fall into Affect and Cognitive Issues, it was felt best to provide special attention to these issues in this way.

1. Group Skills

a. These children generally could not organize their ideas when working in a non-adult-directed group setting. It seems clear that students from a traditional class setting need a framework and/or guidance when working in a group.

2. Group Affect

a. Without adult leadership (the only kind specifically utilized in this pilot), the group activities disintegrated into hassling. It remained relatively good natured, but it was indeed interpersonal in nature.

II. Problem Feasibility for Teacher

A. Time

1. Overall time needed to complete problem

a. Estimated at 4-6 hours

b. Possibly tolerated but pushing upper limits for traditional teachers.

2. Student/Teacher contact time

   a. As it stands now, teacher supervision would be required most of the time.

   b. This requirement is probably not reasonable to expect fulfillment on.

B. Teacher Skills

   1. As it stands now, it is difficult to list teacher skills. It does seem, though, this issue needs careful attention since it seems possible that too much may be expected of the "typical classroom teacher."