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ABSTRACT

A study assessed third- through sixth-grade children's comprehension of selected problem-solving segments from SQUARE ONE TV. A sample of 140 children, equally distributed among the four grades, with 49% girls and 51% boys, and an ethnic composition of 56% White, 22% Black, 19% Hispanic, and 3% other, and 3% other, were randomly assigned to viewing groups of three students of the same sex. Each group was shown two segments separated by a 5- or 6-week interval and assessed afterwards in a group interview for their ability to remember mathematically relevant information, understand the mathematical concepts and problem-solving principles, and extend the relevant concepts to new problem-solving situations. In addition, children were asked to describe their feelings upon reaching the solution of the problem and to recall as much as possible about previously viewed segments. Data analyses suggested the following conclusions: (1) segments' problem-solving content appeared to be accessible to children throughout the target age range; (2) satisfactory response rates began at 65% for third-graders and increased with age, indicating age-appropriateness of the segments; (3) children were able to extend problem-solving principles to new situations; (4) the segments provided motivating context for mathematical "happy," "glad," and/or "proud" suggested that SQUARE ONE TV characters serve as positive role models for problem solving. (MDH)

SQUARE ONE TELEVISION:

The Comprehension and Problem-Solving Study

Final Report

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The Comprehension and Problem-Solving Study

Final Report

I. EXECUTIVE SUMMARY

Purpose of the Study

The primary purpose of this study was to assess children's comprehension of selected problem-solving segments from **SQUARE ONE TV**. This was accomplished through an examination of third through sixth grade children's ability to recall, understand, and extend to new situations the problem-solving information and principles presented in the segments. At the same time, children's understanding and perceptions of the mathematical concepts presented in the segments were assessed. Finally, children's perceptions of the feelings and attitudes of the problem solvers shown in the segments were examined.

Sample

The children interviewed were 140 third through sixth graders (approximately 50% boys and 50% girls at each grade level) taken from a public school in upstate New York; 56% of the children were white, 22% were black, 19% were Hispanic, and 3% were other minorites. Their socioeconomic backgrounds ranged from lower middle to middle class. The children were selected by the school principal to be representative of average ability.

Method

Each child was assigned to a viewing group with two other children of the same age and sex. The group was shown two segments separated by a five- or six-week interval. After watching each segment, children were videotaped in an in-depth, task-based interview lasting about one hour. The questions were designed to evaluate the degree to which they: a) remembered mathematically relevant information from the segment (particularly what the problem and solution were and how the character reached the solution), b) understood the mathematical concepts and problem-solving principles underlying but not fully explicated in the segment, and c) could extend the relevant concepts to new problem-solving situations. Raters subsequently coded responses on a scale from fully correct to incorrect.

Following these questions, the children were asked to describe how the problem solvers felt upon reaching the solution and what sort of mathematics (if any) was involved in the solution. (In fact, all solutions required some form of mathematics).

In addition, to examine the children's longer term recall of the segments, each group's second session included a request to recall as much as possible about the segment the group had seen five or six weeks before.

Summary of Results

The data suggest several important conclusions:

o The segments' problem-solving content appears to be accessible to children throughout the target age range. Even the youngest children were able to recall important problem-solving information, answering approximately 80% of recall questions satisfactorily. Performance increased with age, reaching over 90% for sixth graders.

o The segments appear to be age-appropriate as well. Third graders gave satisfactory answers to 65% of the questions aimed at assessing their understanding of the segments' underlying mathematical and problem-solving content, and performance increased with age (sixth graders answered more than 80% satisfactorily). Thus, it seems that the segments are neither so difficult that virtually no child can understand them, nor so easy that third graders perform as well as sixth graders. Still, it should be remembered that even third graders answered more than two thirds of these questions correctly, despite the fact that some of the material presented in the segments had not been covered in their mathematics classes yet and was completely new to them.

o Further, children were able to extend the problem-solving principles presented to new situations. In some cases, they imitated the procedures used by the characters in the segments. In others, they used a variety of new methods; for some extension problems, older children used a more abstract method whereas younger children used the hands-on, trial and error method demonstrated in the segment.

o The segments appear to provide a strong motivating context for mathematical problem solving. For example, children of all ages played the multiplication game presented in one segment with high enthusiasm. Indeed, after another segment, children became so involved in solving extension questions that they continued to work on solutions until they had to be told to stop at the end of the session. These findings suggest that **SQUARE ONE TV** can provide a highly motivating springboard for learning mathematics

o In almost all cases, children perceived the characters as "happy," "glad," and/or "proud." Typically, the children tied their explanations of these perceptions to the characters' having solved the problems at hand or to the fact that in doing so, they had demonstrated competence and gained respect. Considered along with **SQUARE ONE TV**'s ability to motivate children, this finding suggests that **SQUARE ONE TV**'s characters may be able to serve as positive role models for problem solving. Additional research in Season II will examine this issue further.

II. INTRODUCTION

Purpose of the Study

SQUARE ONE TV, a television series about mathematics for 8- to 12-year-old children, has three goals, which, briefly stated, are:

I. To promote positive attitudes and enthusiasm for mathematics;

II. To encourage the use and application of problem-solving processes;

III. To present sound mathematical content in an interesting, accessible, and meaningful manner.

A full elaboration of the goals appears in Appendix A.

The purposes of The Comprehension and Problem-Solving Study relate directly to these goals. The principal aim was to examine children's comprehension of selected problem-solving presentations from SQUARE ONE TV. More specifically, it focused on their ability to recall and understand problem statements, solution processes, and solutions. It also examined the extent to which they were able to extend their understanding to new problem-solving situations, and the processes they employed to this end. At the same time, it assessed their understanding and perceptions of mathematical concepts presented in the segments. Finally, it explored children's perceptions of the feelings and attitudes of the problem solvers portrayed in the sketches.

Approach

The approach chosen for the study involves in-depth task-based interviews -- one-on-one conversations about some task or tasks that the child is asked to do. The interview is typically constructed to probe beneath the surface -- to explore underlying reasoning that children are employing and misconceptions that may be present. The goal is to go beyond right or wrong answers in search of the thinking processes that the child is using.

Over the past decade the task-based interview has proven to be a particularly fruitful way of determining in detail what children -- especially children of elementary school age -- can do and what they understand. (See Davis [1984] for a good discussion of the methodology.) Dozens of researchers have used it successfully, and the research field has been immeasurably enriched by the insights gained through its use.

In particular, the interview methodology seemed to be a thoroughly appropriate tool to use in examining the impact of **SQUARE ONE TV**, especially because it could be tailored to the specific aims of the study. Interview protocols were constructed around a number of individual problem-solving segments from the show. In keeping with the study's overall aims, as described earlier, these interviews probed systematically for children's ability to recall, understand, and extend material in the segments, and for their perceptions of the characters' attitudes and how mathematics was used. (The exact procedures used are described in detail in the "Methods" section of this report.)

This is a considerable amount of information to gather. On the basis of prior experience, including an earlier pilot study (Peel, Rockwell, Esty, Gonzer, & Sauerhaft, 1987), it was anticipated that interviews capable of capturing a sharp picture of a child's reactions to a particular segment would take approximately one hour to conduct.

This determination of interview length, considered in conjunction with other design issues, shaped the overall structure of the study. Factors that were considered included:

- Sample characteristics. Clearly both sexes and all the target grade levels (three through six) should be involved. The sample should include children from two socioeconomic levels: lower middle and middle class, as well as a variety of ethnic backgrounds.

- Degree of longitudinality. Ideally a study such as this should take place over one or more school years to track possible growth. Time and budgetary constraints made this impossible; nonetheless, a design was employed that included the testing of the same children on two different segments separated by a six-week interval. This also provided the opportunity to test for delayed recall of the first segment.

- Level of interviewer autonomy. Some of the classic work in this area has been done by interviewers (Krutetskii, 1976; Piaget, 1952) who have had complete autonomy to follow promising avenues as they presented themselves. While there are some advantages to that approach, it seemed inappropriate in the present context. A more tightly structured and controlled procedure was adopted because it allowed full comparability across interviews and interviewers, and of course it permits unambiguous replications later on.

o <u>Number of participants per interview</u>. Given any fixed amount of time available for interviews, one can increase the total number of subjects involved by interviewing more than one at a time. Building on experience from earlier studies, the interviews were conducted with three same-sex students simultaneously, rather than with individuals. The "Methods" section describes the techniques employed for minimizing inter-child contamination.

III. METHODS

Sample

The original subject list for this study included a total of 120 children from the New Windsor School in Newburgh, N.Y. -- 15 boys and 15 girls from each of grades three, four, five, and six. The list was constructed by the school principal, who selected "average ability" students from two classes at each grade level. The ethnic composition of the sample was 62% white, 22% black, and 16% Hispanic. According to the principal, the socioeconomic background of the student population ranged from lower middle to middle class.

Subjects were assigned randomly to one of 40 viewing groups with the constraint that each group consisted of three children of the same sex and from the same grade. When attrition occurred, a replacement of the same sex was chosen from the same grade. As a result, a total of 140 children participated in the study. The ethnic composition of the final sample was 56% white, 22% black, 19% Hispanic, and 3% other. As Table 1 indicates, the final sample included 49% girls and 51% boys.

Table 1
Numbers of Boys and Girls by Grade

Sex	Grade				Total
	3	4	5	6	
Girls	18	15	18	17	68
Boys	20	16	19	17	72
					140 Total

Segment selection

The Study examined the comprehension of 10 problem-solving segments from **SQUARE ONE TV** (see Appendix B for segment descriptions):

A. "Bobo's Dilemma"

B. "I Love Lupy -- Licorice"

C. "Duelists"

D. "In Search of the Giant Squid"

E. "Photograph All About It"

F. "Callous -- The Survey"

G. "But Who's Multiplying?"

H. "Kubrick's Rube"

I. "Phoneymooners -- Hole in the Wall"

J. "Daddy Knows Different -- Stainless Forks"

The segments were selected according to the following criteria:

- The segment is classified as a problem-solving piece, i.e. one that was coded for Goal II. (See the Statement of Goals for **SQUARE ONE TV**, Appendix A.)
- The segment is classified as presenting at least two mathematical topics covered in Goal III.
- The segment is a studio sketch, rather than a film, animation, song, interstitial "bumper," or "Mathnet" episode.
- The segment is at least two minutes in duration.

These criteria ensure some degree of comparability across segments. In addition, no segment selected for inclusion in this study has been tested in either The Premiere Week Study (Peel et al., 1987) or the CTW Mathematics Series Test Show Evaluation (Children's Television Workshop, 1986); thus testing of these segments is not replicated elsewhere.

To create a set of 10 test segments that are as representative as possible of the diversity within the series, segments representing a variety of Goal III subgoals, some repeated parodies, and a variety of cast members were included. (See Appendix C.)

Design

The 10 selected segments were grouped into five pairs, and each of the 40 triads watched one pair. Table 2 indicates how the student triads were assigned to segments.

Table 2
Number of Children Assigned to Test Segments, by Grade and Sex

	Grade							
Segment Pair	Third		Fourth		Fifth		Sixth	
	Girl	Boy	Girl	Boy	Girl	Boy	Girl	Boy
Segment A,B	3	3	3	3	3	3	3	3
Segment C,D	3	3	3	3	3	3	3	3
Segment E,F	3	3	3	3	3	3	3	3
Segment G,H	3	3	3	3	3	3	3	3
Segment I,J	3	3	3	3	3	3	3	3

40 Interview Triads

Testing took place on 10 Thursdays over the course of 12 weeks. Each testing day involved a total of eight interview triads, one of boys and one of girls from each of the four grade levels. Five test days (i.e. five to six weeks) after viewing the first segment, the same triads viewed the other segment in the segment pair under the same conditions. On any test day, third and fifth graders saw one of the segments, and fourth and sixth graders saw the other one. (See Table 3.)

Table 3
Order of Segment Viewing by Grade

	Grade			
	Third	Fourth	Fifth	Sixth
Segment A	Week 6	Week 1	Week 6	Week 1
Segment B	Week 1	Week 6	Week 1	Week 6
Segment C	Week 7	Week 2	Week 7	Week 2
Segment D	Week 2	Week 7	Week 2	Week 7
Segment E	Week 3	Week 8	Week 3	Week 8
Segment F	Week 8	Week 3	Week 8	Week 3
Segment G	Week 9	Week 4	Week 9	Week 4
Segment H	Week 4	Week 9	Week 4	Week 9
Segment I	Week 10	Week 5	Week 10	Week 5
Segment J	Week 5	Week 10	Week 5	Week 10

Procedure

Prior to the study, the principal sent permission slips home to parents. (See Appendix D.) On the first day of the study, all children in grades three through six viewed Show 101 in the school auditorium. At the end of the day, the Viewing Questionnaire was distributed. The questionnnaire asked each child if she or he had ever watched SQUARE ONE TV at home, and if so, approximately how many times. (See Appendix E.) This questionnaire was completed again at the end of the Study. On the following day, testing began.

At the beginning of each test session, researchers explained the procedures to the two interview triads at each grade level. (See Appendix F for instructions for interviewers.) The six children then viewed the test segment together. After viewing, they were divided by sex and interviewed in two separate rooms. Each interview was videotaped. Each test session, including viewing and interviewing, lasted approximately one hour. This procedure was followed on 10 Thursdays.

The interview protocol for each of the 10 test segments included a three-tiered system of items designed to examine recall, understanding, and extension. This system was piloted in an earlier study (Peel et al., 1987), and is described below.

During the second test session of each segment pair, the interviewer began with a question about the segment seen five or six weeks before: "What happened in the story you saw last time?" The intention here was to probe for children's recall of a SQUARE ONE TV segment over time, five or six weeks after viewing.

Levels of questions

As indicated above, a three-tiered system of questions was used. At the lowest level were the "Recall" ("R") questions. These tested whether the children could recall mathematically relevant information from the segment. In particular, this included recall of the problem statement, the processes or procedures used to solve the problem, and the solution of the problem. (In some cases, of course, the problem becomes progressively better defined as the segment unfolds, and the solution may not be completely determined even at the end.)

The next level was "Understanding" ("U") questions. These were aimed at ascertaining the child's understanding of concepts that are not fully explicated in the segment. In some cases they probed for background information, while in other cases they concerned the relationship between elements of the segment that are not explicit in the sketch. Often they dealt with the function or purpose of the mathematics used or the characters' reasons for performing whatever mathematics was involved.

The final level was "Extension" ("E") questions, which went beyond the boundaries of the segment itself. They probed for the child's ability to apply the concept in the segment to new (although usually similar) problem-solving situations. Often these were very difficult questions, which not even the oldest children would be expected to answer successfully. Rather than strive for some level that most children might attain, the goal here was to determine how far some students could take the ideas presented in SQUARE ONE TV segments.

At the end of each of the interviews, children were asked a series of questions designed to probe for children's perceptions of the problem solver, of the other main character(s) in the sketch (when applicable), and of the mathematics presented.

All questions were fully written out so that the interviewers would be completely consistent. (See Appendix G.)

Presented below are examples of each type of question, taken from the interview on the segment "Daddy Knows Different -- Stainless Forks," in which Rusty gives his father the option of paying him a fixed allowance or starting with a penny and then doubling the previous day's amount for a month. (A summary of the results of the full set of questions posed about this segment appears in a later section of this report, together with a brief description of the segment itself.)

<u>Recall</u>:	How did Rusty and his dad figure out how much money Rusty would get? What did they <u>do</u> to figure out how much money Rusty would get?
<u>Note</u>:	This is classified as "R" because all of the information is explicitly presented in the segment.
<u>Understanding</u>:	[Direction to interviewer: Put one dollar, one quarter, and two pennies on the table.] Rusty would make this much money at the end of one week -- $1.27. So how could he make $10,737,418.23 at the end of 30 days?
<u>Note</u>:	This is classified as "U" because it is <u>not</u> explicitly presented in the sketch. It <u>does</u> <u>not</u> go beyond the sketch, but it is fundamental to a full understanding of it.
<u>Extension</u>:	Let's say that <u>you</u> were going to get an allowance at home for one week, OK? Let's also pretend that you have a choice: you can either

get 50 cents a day for one week; or you can use Rusty's plan for one week -- you know, a penny the first day, double that the second day, and so on for one week. Which way would you want to get paid? [Give each child a pad and pencil.]

<u>Note</u>: This is classified as "E" because it goes beyond the boundaries of the sketch; it asks a question that was not posed during the segment. The viewer can follow the action successfully without even contemplating alternatives to the payment plan described in the story.

The questions designed to probe for children's perceptions of the problem-solvers and mathematics in the segment "Daddy Knows Different -- Stainless Forks" were:

How do you think Rusty felt when they solved the problem? (Probe: How do you know? Why?)

How do you think the dad felt when they solved the problem? (Probe: How do you know? Why?)

Was there any mathematics in the TV story today? (Probe: What was it?)

<u>Interpretations of responses</u>

Clearly, the kinds of questions that can tap the complex thinking that **SQUARE ONE TV** segments elicit are not adequately measured by simple right-wrong or multiple choice checklists. Indeed, in the setting of carefully conducted in-depth interviews, one can expect a range of responses as broad as the range of children involved. Of course, these responses can be recorded and then individually analyzed, but this provides no overall indication of what children of various ages get from viewing the segments. Therefore, to create a structure with which patterns of responses could be discerned, each child's answer was analyzed against a carefully delineated hierarchy of possible response types. These were coded as "Y" (fully correct and appropriate), "M" (various mid-level responses that were further broken down into subcategories), or "0" (incomplete, incorrect, or inappropriate). As an example, consider the "R" question above and its guide for coding children's responses:

Y	Rusty made a list <u>and</u> started with a penny <u>and</u> doubled for 30 days
M+	List <u>and</u> doubled; no mention of penny or 30 days
M	Either one of above
M-	E.g. "Added all the amounts he got for each day"
0	Nothing, or "I don't know"

Any responses that did not closely fit one of the examples given in the coding guide were individually assigned a level by one of the senior researchers on the project.

<u>Maintaining individuality of responses</u>

Recall that the children were interviewed in groups of three, with each triad of the same sex and grade level. While this tripled the number of children that could be seen in a given amount of time, it introduced the possibility of subjects influencing each other. In particular, children could simply agree with a peer's correct response and thus appear to be at a level higher than would be the case if they were interviewed individually. A number of techniques were used to control for this: (1) starting with a child who did <u>not</u> have his or her hand raised; (2) asking the second or third child to rephrase the first child's response; and (3) watching carefully for the genuineness of a child's agreement with a previous answer (here the videotaping was enormously helpful). In some cases extension questions with different numerical values could be posed to each child, so that in effect they were responding as unaided individuals.

IV. FINDINGS

This chapter presents findings from the current study in three sections. They are Overall results: comprehension, Overall results: perceptions of problem solvers and mathematics, and Segment summaries.

These sections, combined, yield both a broad and highly detailed view of target-age children's comprehension of the 10 problem-solving segments.

Overall results: comprehension

Figure 1 combines data from all grades and both sexes to give an overall summary of the level of response to the three types of comprehension questions across all 10 segments. (For data on individual segments, see the Segment Summaries section below and Appendix H.) as was also apparent in The Premiere Week Study, (Peel et al., 1987) "R" questions were the easiest for children while the "U" and "E" questions were progressively more difficult. This pattern holds whether one considers the "Y" (fully correct) level of response or the "Y" and "M" (mid-level) responses combined. (The levels "M+", "M," and "M-" have been collapsed into a single level for Figure 1 and subsequent figures.)

Figure 1

Percentage of "Y" (Fully Correct) and "M" (Mid-Level) Responses, by Type of Question

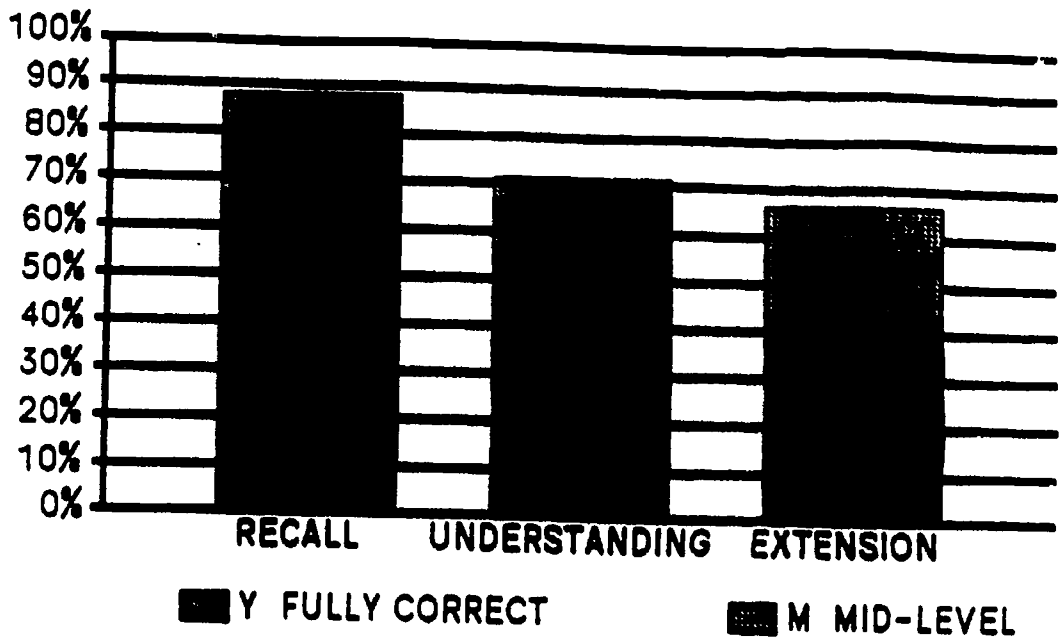
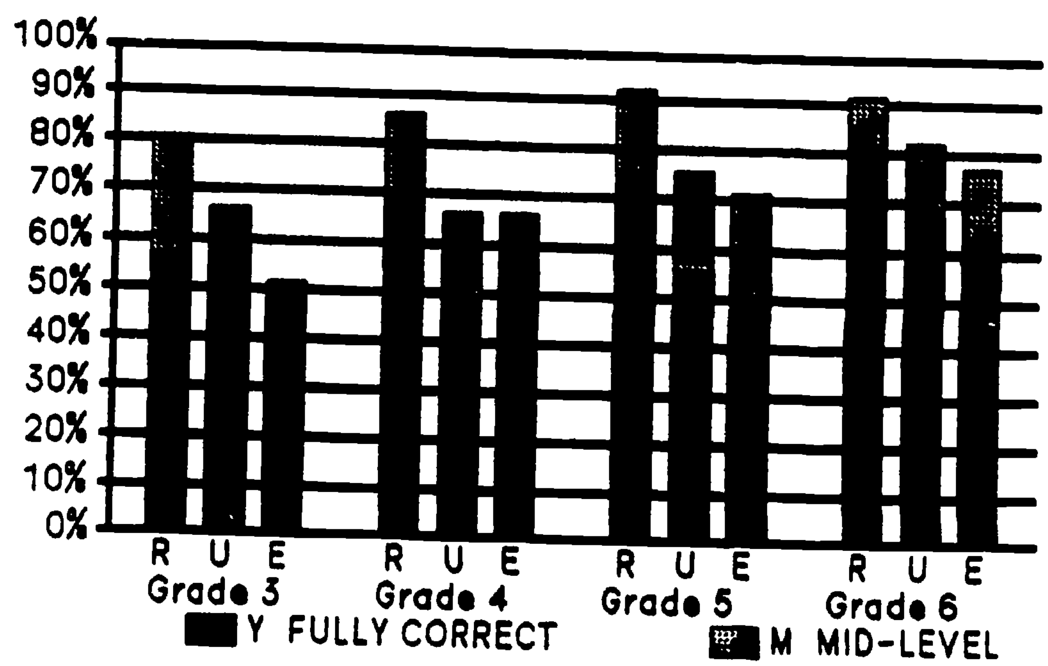


Figure 2 presents data for each grade level. Here again, the decreasing "R"-"U"-"E" phenomenon is evident at each grade. Also, as one might expect, performance increases with grade level for each type of question.

Figure 2

Percentages of "Y" (Fully Correct) and "M" (Mid-Level) Responses, by Type of Question and Grade



The overall level of performance is important. It indicates that the segments, on the whole, are appropriate at some level even for third graders, as evidenced by the fact that approximately 80% of their responses to recall questions were either partially or fully correct, <u>and</u> over 50% of their responses to extension questions were partially or fully correct. In addition, it is apparent that the segments are not too easy for sixth graders; although approximately 90% of their responses to recall questions were either partially or fully correct, less than 80% of their responses to extension questions were partially or fully correct.

There were virtually no sex differences in overall performance on recall, understanding, and extension questions, as can be seen in Figure 3.

Figure 3

Percentages of "Y" (Fully Correct) and "M" (Mid-Level) Responses, by Type of Question and Sex

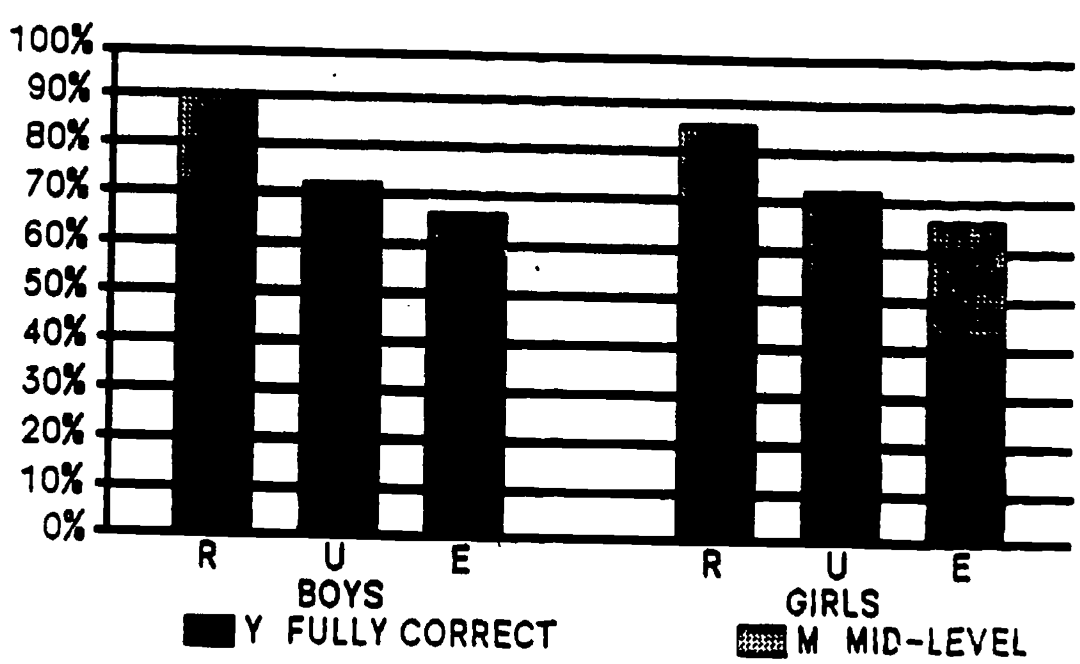
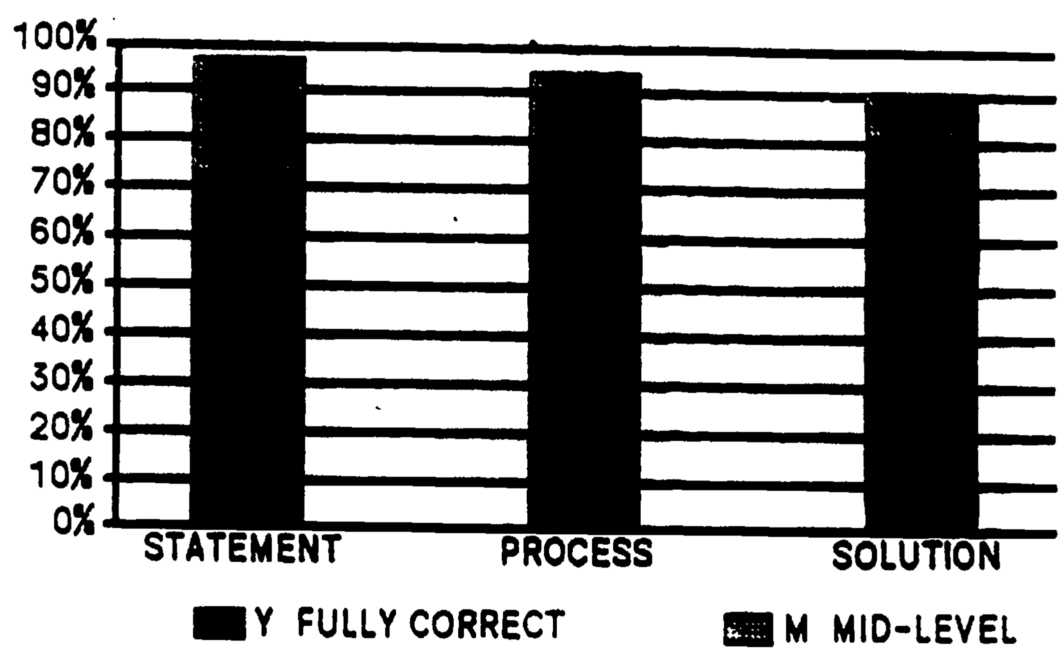


Figure 4 combines data across segments, grades, and sexes for a subset of recall questions: those specifically designed to probe for recall of the problem statement, recall of the process of solution, and recall of the solution. As the figure indicates, nearly 100% of the responses to questions about the problem statement were either fully or partially correct. In addition, at least 90% of the responses to the other two questions were either partially or fully correct. In short, recall of problem solving was very high for all children.

Figure 4

Percentages of "Y" (Fully Correct) and ("M") (Mid-Level) Responses to Recall of Problem-Solving Questions

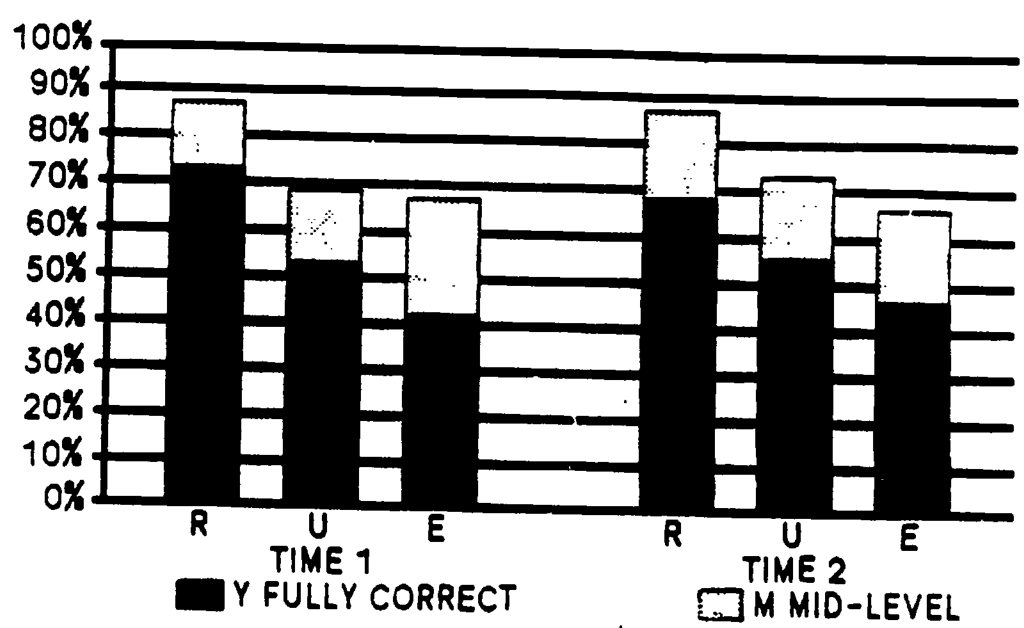


To determine whether there were any overall differences in performance between the first round of testing and the second round of testing (six weeks later), the comprehension data from each round were combined across segments. Figure 5 indicates there were virtually no differences in overall perfomance between the first round of testing (Time 1) and the second round of testing (Time 2).

Prior to the conduct of the study, no one knew if performance would change over time. If, for example, increases were found, they might have been attributable to a variety of factors including: increased comfort with interviewers; increased familiarity with the type of questions being asked and consequent increased attention during viewing; and increased **SQUARE ONE TV** viewing at home following its introduction at school. Because of an _a priori_ sensitivity to the fact that **SQUARE ONE TV** viewing might increase at home during the course of the study, and that it might help interpret any Time 1-Time 2 increases, researchers administered a Viewing Questionnaire. An increase in viewing did occur. (See Appendix I for results.)

Figure 5

Percentages of "Y" (Fully Correct) and "M" (Mid-Level) Responses, by Type of Question for Time 1 and Time 2



Overall results: perceptions of problem solvers and mathematics

Looking across the 10 segments, some overall patterns in the responses to the "perceptions" questions are apparent. In most cases, children had very positive perceptions of the problem solver. Adjectives used to describe him or her included "happy," "glad," "proud," or "relieved." When asked how they could tell the character felt this way, children tended to refer to the characters' facial expression or his or her physical movements.

More important, when asked *why* the character might have felt that way, responses were more varied, and in general, three themes emerged. One common response was that the problem solver felt good simply because he or she solved the problem or he or she "figured it out." Second, some children instead referred to the positive outcome of solving the problem. Finally, others focused on the character's demonstrated competence or gained respect.

The findings are similiar for the second character. In almost all cases, children perceived the other character in the segment positively. In explaining why he or she might feel happy or glad, again they referred to the fact that the problem was solved, the positive outcome of the solution, or the competence of the problem solver.

The final perception question probed for children's perception of the mathematics. In every segment, almost all of the children perceived there to be mathematics. The only exception was "Bobo's Dilemma" where 6 out of 24 children did not answer affirmatively, probably because there are no obvious mathematical calculations in the sketch.

In general, when asked what the mathematics was in a given segment, children tended to focus on multiplication, subtraction, addition and "counting." This is not surprising given the pervasive emphasis on numerical computation found in most elementary mathematical texts.

Segment summaries

The next 10 sections describe in detail the results obtained from the 10 segments that were chosen for study. The format of each section is identical; they include the following subsections:

The first is a very brief description of the segment's plot. This is followed by a subsection on mathematical content that highlights some of the mathematical points that the segment attempts to convey.

The next subsection describes relevant school experience -- mathematical knowledge the children might have brought to the interviews from formal coursework. The textbook series used by the participating children is the 1985 edition of Addison-Wesley Mathematics, (Eicholz, O'Daffer, & Fleenor, 1985). While the discussion of relevant school background is limited to that text, the Addison-Wesley series is fairly typical of the vast majority of mathematics books used by third- through sixth-grade students throughout the country. (It should be noted that two elementary mathematics programs -- Real Math, (Willoughby, Bereiter, Hilton, & Rubinstein, 1985) and the Comprehensive School Mathematics Program, (McREL, 1985) are significantly different from the usual series. The remarks below are not applicable to those series.)

In many cases the relevant coverage in the Addison-Wesley text is very brief -- at most one or two lessons. No attempt has been made to determine if a particular child who was interviewed actually was exposed to that particular topic (by checking attendance records or by asking the child's mathematics teacher, for instance). In other cases some relevant background may have been acquired through other avenues. In addition to parents, friends, and informal educational experiences (television, museums, etc.), certain formal classes might also be relevant, particularly treatments of maps and graphs in social studies. Again, no effort has been made to determine precisely what these might be for the children participating in the study.

The principal subsection of each section is a summary of results, further subdivided in terms of recall (including recall six weeks after viewing), understanding, and extension, and perceptions questions.

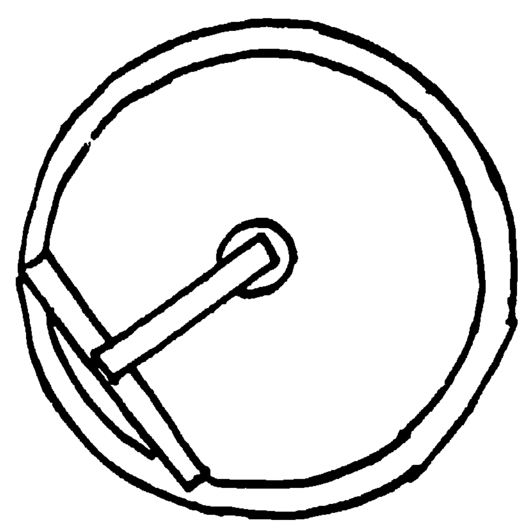
Finally there is a section entitled Discussion and formative implications in which suggestions are offered for Season II.

"BOBO'S DILEMMA"

Description

Bobo the clown must get from an outer circus ring to the center platform. He is given two boards to help him; however, the boards are each 6 1/2 half feet long, and the center platform is 7 feet from the outer ring. Neither Bobo nor the boards can touch the ground. After several attempts, Bobo finds a solution: he places one board so that just its ends are on the ring, and he places the second board perpendicularly from the midpoint of the first board to the center platform. See Figure 6 below for a sketch of Bobo's solution.

Figure 6
Bobo's Solution



Mathematical content

At one level "Bobo's Dilemma" can be thought of as an opportunity to experiment with geometrical objects in an attempt to construct a configuration that meets criteria given in the problem. At a more abstract level it serves as an introduction to convex and non-convex shapes: even though both endpoints of a line segment (modeled by a board) are on the ring, part of the board extends into it; it is this non-convexity of the ring that leads to a solution of the problem.

<u>Relevant school experience</u>

Geometry is part of the Addison-Wesley mathematics curriculum at all grade levels, although the chapter devoted to geometry uniformly appears late in the year (beyond page 200). The content is very heavily slanted toward vocabulary (particularly different kinds of shapes) and relations like congruence, similarity, parallelism, and so on. There is essentially no geometric problem solving anywhere in the curriculum -- certainly nothing like the dilemma that confronts Bobo in this sketch.

<u>Summary of results</u>

<u>Recall</u>

All of the third, fourth, fifth, and sixth graders recalled the problem statement and accurately recounted that Bobo had to get to the center platform from the outer ring without touching the ground. They described his initial attempt (with one board that was too short to reach the center) and his final solution. Several children even recalled both the distance from the ring to the center and the length of the boards. One sixth-grade boy thought about the problem beyond the given story elements, saying the distance from the ring to the center platform "was too far to jump."

Six weeks later, all of the children recalled that Bobo was faced with the task of getting to the center of the ring, and a few mentioned the fact that he could not touch the ground. All but one of the children also indicated that Bobo was given boards to help him solve the problem.

A typical response came from a fourth grader who explained, "The clown had to get to the center of the circle. Somebody gave boards to get across." Two sixth graders came close to recalling the actual lengths of the boards: one child thought they were 5 feet long, and another guessed 7 or 7 1/2.

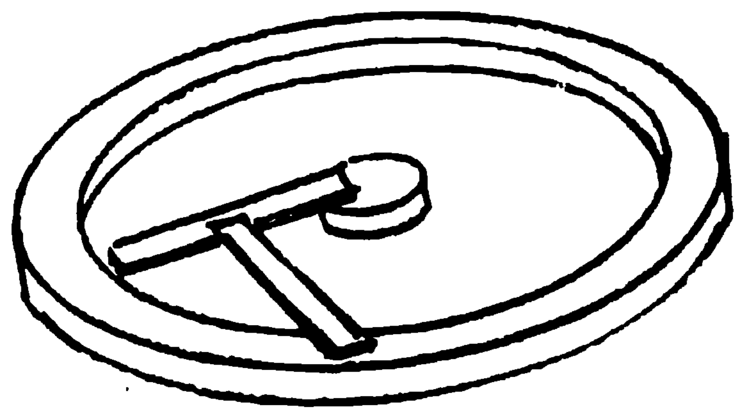
Understanding

A model circus ring with a center platform and boards similar to those in "Bobo's Dilemma" were constructed as props to probe for understanding of the concepts involved in this segment. All of the children tested were able to use the prop boards and circus ring to demonstrate how Bobo solved the problem.

In the understanding questions, children were tested for their ability to apply the rules of "Bobo's Dilemma" to new situations. These questions revealed a variety of conceptions of the problem and its rules. For example, the children were shown a prop configuration where the two boards connected the ring to the platform but also touched the ground. Here most third-, fourth-, and fifth-grade girls did not use knowledge of the rules they had demonstrated earlier, that the boards could not touch the ground, and thus conclude that this configuration could not solve Bobo's problem. (See Figure 7.) These children either thought that this configuration could solve the problem, or said it would not solve the problem for reasons such as, "It would collapse. He'll fall and get hurt." "If he walked [on it] it would have fell [sic]."

Sixth-grade girls and most boys across the grades recognized that this configuration would not solve Bobo's problem because the boards were touching the ground.

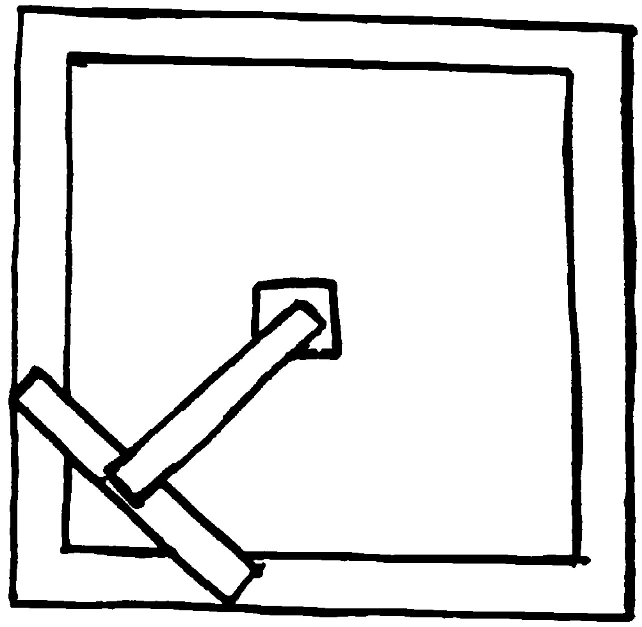
Figure 7
Incorrect Configuration -- Board Touching Ground



Extension

The children were given two boards and a square circus "ring" with an inner platform to assess whether they could extend the rules of the problem and its solution to a different situation. (See Figure 8.) Most of the children correctly placed the two boards from the outer square to the center platform using the rules of the segment. Some of the older children recognized immediately that one of the boards should straddle a corner of the ring, as in Figure 8. In both of the third-grade groups, however, the children first tried to align the board with one side of the square so that no part of the board extended beyond the ring. Only after several attempts with this unsuccessful approach did the groups then arrive at the correct solution.

Figure 8
Solution with Square Circus "Ring"



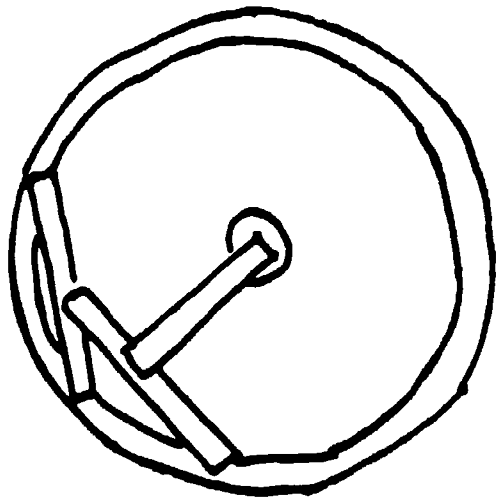
Next, returning to the original circular ring, children were asked a "trick" extension question in which one longer board was extended from the center platform to the outer ring. They were not told that the board was longer, nor were they reminded of the fact that Bobo was starting from the outer ring. They were asked if this solution would solve Bobo's problem. Several third, fourth, and sixth graders recognized that this board fit across, and that the one in the segment did not, but, because this board spanned the gap, several of these children pronounced the problem solved. They also failed to notice that the board was placed from the center to the outer ring, rather than from the outer ring to the center. Explaining why this did not solve the problem, several of the girls and boys in both grades expressed concern that Bobo would "tip and fall off" if he used only one board. One sixth-grade boy explained incorrectly that this new solution would solve Bobo's problem because "he could walk across it. Getting in he needed two boards, getting out he only needed one." Only one child, a fifth-grade boy, clearly articulated both parts of the trick: that the new board spanned the gap by itself and that it was extended from the center platform. His two peers immediately agreed with his explanation.

Children were then given two shorter boards and asked if there was a way Bobo could get from the outer ring to the center platform. These boards were too short; there was no solution to this problem. This extension question was asked in an attempt to look at how children deal with an insoluble problem. Are they tied to the confines of what they saw in the segment, or are they willing to consider a problem insoluble? The children's exhaustive attempts to solve this extension problem were striking.

Seemingly unconvinced that a peer's unsuccessful attempt to solve the problem would not work, children would often replicate each other's ideas. Only after this effort would a child suggest that the problem could not be solved, or, as one third-grade boy said, "Ain't no way." Many of the children did not want to stop experimenting with the props until they had found solutions acceptable to them.

Finally, the children were asked to do the problem with three boards, all too short to reach the center platform individually or in pairs. Across all triads, children tried a variety of strategies, and one fifth-grade boy and one fifth-grade girl found a solution. (See Figure 9.)

Figure 9
Solution with Three Shorter Boards



Discussion of this extension problem revolved around hypotheses that considered physical factors. Suggestions included using a heavier board, glueing the boards together, using a weight to secure a board overhanging the edge of the ring, or using rope to tie the boards together. All of these suggestions correctly took into account the fact that if the boards were heavier or anchored at the end, Bobo could walk across them. These children also considered Bobo's weight and the weight of the boards in thinking about the problem.

Perceptions

Not surprisingly, when asked how Bobo felt when he solved the problem, all of the children responded positively. The majority of them described Bobo as "happy," and said that they knew this because he was "smiling," "dancing," or "jumping up and down." As one fourth grader explained, "...'cause I saw the smile on his face - he kept trying and he didn't get it , and then he finally got it." A number of children referred to the fact that Bobo had solved the problem in the discussions of his feelings.

All of the children also had positive perceptions of how the circus audience felt when Bobo solved the problem at the conclusion of the segment. Most said they knew the audience was "happy" because they were cheering. Others mentioned Bobo's successful completion of the task set for him. For example, one sixth grader described the audience as "amazed, because he did something they probably couldn't do." Another child focused on Bobo's persistence in solving the problem, saying, "They know he just didn't give up and the next time he won't give up."

Out of the 24 children questioned, 18 said that there was mathematics in the Bobo segment. When asked what the mathematics was, younger children generally referred to addition and subtraction. Older children demonstrated an understanding of problem solving as mathematics; as one sixth grader said, " I think it had to do with math because they were telling him the size of the boards and they proved that you could do certain things with certain boards, and you had to figure out stuff and get it across like in math."

Discussion and formative implications

In summary, all of the children recalled Bobo's problem, his initial attempt to solve the problem, and his solution. When given a model of the circus ring, all of the children could also reconstruct Bobo's solution. On the extension questions, children used a variety of strategies to solve the problems presented and attacked these problems with perseverance and enthusiasm. Older children, in particular, grasped the essential feature of the geometric configuration to solve the problem. This is compelling considering the dearth of geometric problem solving in the typical elementary school classroom.

"Bobo's Dilemma" was a successful segment in many ways. The problem at hand was clearly established, and the solution given was understandable, yet not obvious, to the children viewing. In addition, it is evident from the extension questions in the interviews, that the "dilemma" presented is interesting to this age range. Because of this, it is not surprising that all of the children had positive perceptions of Bobo, often relating his pleasure (or the audience's) to the fact that he had solved a difficult problem.

"I LOVE LUPY -- LICORICE"

Description

Lupy is newly hired by a candy manufacturer to cut 5-inch and 7-inch sticks of licorice from strands that come from the factory in 2-foot lengths. The aim is to do it in such a way that no licorice is left over. She tries a number of ways (for example, cutting a single 5-inch piece or three 5's and a 7) all of which leave some unused licorice. Finally, she realizes that two 5-inch sticks and two 7-inch sticks can be obtained from a 2-foot strand with no waste.

Mathematical content

This sketch treats two important mathematical ideas. The first is that the length of a line segment formed by joining two segments end-to-end is the sum of the lengths of the constituent parts. The second is the more complex notion that certain numbers can be expressed as the sum of the others -- in this case 24 is the sum of 5's and 7's. This idea is taken beyond the sketch in the extension questions.

Relevant school experience

Measurement of length is treated in the Addison-Wesley texts at each of the four grade levels, although it appears in the latter part of the books (after page 300 in all cases). Furthermore, even third graders should be familiar with the addition and subtraction computation involved, since it is reviewed early in the year.

On the other hand, problems like the one facing Lupy -- in which pieces of two different lengths must be formed from a single strand -- are never encountered in this text series. Moreover, problems like some of the extension questions, for which no solutions exist, are rare indeed.

Summary of results

Special note

The testing of the "I Love Lupy -- Licorice" was unusual because a significant change was made in the sketch after the first test date. In its original form, there was no mention (either by Lupy or by the employee who sets the licorice-cutting task) of the fact that 2 feet equals 24 inches, an important piece of mathematical information relevant to the solution of the problem. After testing the segment with third and fifth graders, it appeared that this omission caused some difficulties and resulted in some basic misconceptions. For this reason, the segment was changed prior to broadcast to incorporate the visual message, "2 feet = 24 inches." Since the second version is the final one, it was tested again in all four grades with children who had not seen the first version.

Because the two versions of the segment were both tested in the third and fifth grades, some comparisons between them can be made. When asked "How many inches are in 2 feet?," the children who saw the version of "Lupy" with the overlay did not perform better than those who saw the first version of the segment. Although fifth graders usually knew the answer and the third graders usually did not. Despite this, however, some of the third graders who saw the second version recognized that Lupy was cutting from 24-inch strands. For example, when the group of third-grade boys (who saw the segment with the overlay) were asked how many inches are in two feet, they responded "70," "120," and "60." Two questions later, though, when they were asked what Lupy did to solve the problem, they said, "She put two 5-inch... and two 7-inch to the 24-inch, so she could cut without waste." Therefore, although they did not initially make the connection between 24 inches and two feet, clearly they did absorb this information well enough to apply it to the problem at hand.

In general, if one considers a subset of the nine questions in the interview that draw upon the knowledge that 2 feet equals 24 inches, it is evident that there is a difference in the performance between those children who did see the overlay and those who did not. The majority of these nine questions focus on the mathematics involved in Lupy's licorice cutting; for example, the children are asked how much licorice Lupy had left over when she cut four 5-inch pieces, and why she had that much left over. To get a fully correct answer for both of these questions, the child must answer "4 inches", and explain that 24 minus 20 (4 x 5) equals 4. Looking across this subset of questions, third graders who saw the version with the overlay offered, in total, 17 correct responses out of a possible 54. In contrast, the third graders who saw the version without the overlay achieved only eight correct responses.

Similarly, fifth graders who saw the second version with the overlay made 40 out of 54 correct responses, while those who saw the first version made only 32 (see Table 4). It seems plausible, therefore, that children who saw the second version of "I Love Lupy -- Licorice" benefited from the information presented in the overlay.

Table 4

Frequency of Correct Responses by Grade and Treatment

Grade	Treatment	Number of Y-Level (Fully Correct) Responses	Total Number of Responses
3	With overlay	17 (31%)	54
	Without overlay	8 (15%)	54
5	With overlay	40 (74%)	54
	Without overlay	32 (59%)	54

For the rest of this section, only children's responses to the final version (with the overlay) will be discussed and summarized.

Recall

All children recalled the problem statement with great detail and accuracy, and most recalled the process of solution and the actual solution. All of the children remembered that Lupy was supposed to cut 5-inch and 7-inch strands of licorice, and that she was not to waste any licorice. In almost all cases, they also recalled that she solved the problem by cutting two 5-inch sticks and two 7-inch sticks from each strand. As one third grader explained, "She tried to do the math without wasting none. Two 5's make 10; two 7's make 14; that would make 24 inches."

When asked six weeks later what happened in the segment, 8 of the 11 children recalled that Lupy was supposed to cut licorice without any waste. Four children also remembered that she was supposed to cut the licorice into 5-inch and 7-inch strands. As one third grader explained, "The guy wanted her to cut them all, 7 and 5, he didn't want her to waste any. She kept hiding the wasted ones. If she wasted some, she'd get fired." Two other children instead focused on Lupy hiding the wasted licorice. One fifth grader said, "When the boss came in, she had leftovers on her neck, eyebrows, and shoved in her mouth. He patted her on the back and she swallowed."

Understanding

To examine children's understanding of the process of solution, children were asked why Lupy laid out the licorice pieces next to the 2-foot licorice strand (which was how she solved the problem). Most of the children understood the reason and could articulate it. For example, one fourth grader explained that she did this so that "she could measure them to see if it fit; so she could try something else that may work."

Other understanding questions focused on the mathematics involved in Lupy's trial-and-error efforts to solve the problem. For instance, children were asked how much licorice Lupy had left over when she cut one 5-inch piece, and why she had this much left. Some of the fourth graders and most of the fifth and sixth graders could answer both of these questions. For example, one sixth grader said she had 19 inches left over because, "she only cut 5 inches, and 19 from 24 equals 5."

The third graders had a more tentative grasp of these kinds of questions. Not one of them knew how much licorice Lupy had left over after she cut of a 5-inch strand. However, when children were told that she had 19 inches left over, most could adequately explain why this was true (because 24 - 19 = 5).

Extension

There were three extension questions on "I Love Lupy -- Licorice." The first asked if Lupy could cut three 7-inch sticks and one 5-inch stick from the 2-foot strand. All but one of the children correctly concluded that she could not. As one fourth grader explained, "Two 7's and two 5's are enough for 2 feet. So three 7's and one 5 are more than 2 feet." While most of the children answered the question abstractly, a few of the younger ones had to use manipulatives (narrow strips of heavy black cardboard cut to appropriate lengths) to arrive at the correct answer.

The next extension questions required the children to make 5-inch and 7-inch sticks out of new strands. Each child got a different length strand - 33, 32, or 31 inches. While all but one of the children answered the question correctly, there were marked differences in the processes they used. Most of the fifth and sixth graders obtained correct answers using either addition or subtraction, and the pencils and paper made available to them. A few of them were very quick in their responses, especially two fifth-grade boys who immediately solved the problem in their heads, without using manipulatives or pencil and paper.

In contrast, the younger children were not able to solve the problem abstractly. Instead they used the manipulatives, following Lupy's example of lining up the smaller pieces next to the 31-, 32-, or 33-inch strands. Like Lupy, they justified their solutions with physical comparisons of length. Older children, however, cited arithmetical computations.

In the two final extension questions, children were given problems that were impossible to solve. The first question asked to them figure out how many 5-inch and 7-inch sticks one could cut from a 23-inch strand. All but three children correctly concluded that the task was impossible. In most cases, the approach was trial and error using manipulatives. One fifth grader, however, solved the problem without manipulatives, systematically checking all possibilities. In explaining why it was impossible, he said, "I've done 22 and 24, I've done 7 x 1, 7 x 3; 5 x 1 and 5 x 3." Here he chose not to consider 7 x 2 or 5 x 2 because both represent Lupy's solution to the 24-inch strand and therefore would not work with a 23-inch strand. He also did not consider 7 x 0 or 5 x 0, possibly because neither 5 nor 7 is a multiple of 23.

The final question extended the mathematics presented in "Lupy" into a new context. It required the formation of stamp packets for coin-operated machines in post offices. The packets were to be made by using 6-cent and 9-cent stamps to sell for exactly 50 cents. Because of time constraints, only the more advanced groups of children were asked this question.

Almost all of these children correctly concluded that the task was impossible; no child, however, could give a complete explanation of why it could not be done, either through a systematic enumeration of all the possibilities or a straightforward divisibility argument.

Perceptions

All but one of the children expressed positive perceptions of Lupy. When probed for their reasons, many children said because she figured out the problem, or because she did not waste any licorice and, therefore, would not lose her job. Two children mentioned the possibility of her getting a promotion.

All of the children had positive perceptions of how Lupy's boss felt when Lupy solved the problem. Many children explained that he felt this way because Lupy didn't waste any licorice and, as a result, he didn't have to fire her. About one third of the responses focused on Lupy's competent work. For example, one fifth grader said that the boss felt glad because, "he said she did it nice, better than the other guy they fired. She did a better job." Some children also mentioned the "reward" (a bag of licorice) that the boss gave Lupy, seeing it as a sign of his satisfaction with a job well done.

Almost all of the children said there was mathematics in the segment. Most referred to the adding of 5's and 7's, and one child stated that Lupy used mathematics when "she had to add to see if two 5's and two 7's equals 24." A few children also mentioned the "2 feet = 24 inches" overlay.

Discussion and formative implications

In summary, the interviews revealed that all of the children could recall the problem Lupy had to solve, and most recalled and understood how she solved the problem. In general, fourth, fifth, and sixth graders also evinced a solid understanding of the mathematics involved in Lupy's licorice-cutting, the idea that the length of a line segment formed by joining two segments end-to-end is the same as the sum of the lengths of the constituent parts. Third graders were less successful in the questions that probed for this concept. In response to the extension questions, almost all of the younger children solved the problem using the heuristics Lupy modeled: lining up the 5-inch and 7-inch sticks against the longer strand. Older children, used another, more efficient strategy. They were usually able to solve the extension questions abstractly, either using paper and pencil or simply doing the mathematics in their heads.

The interviews on "I Love Lupy -- Licorice" revealed children's lack of familiarity with linear measurement and, in particular, relevant unit conversions. This is not surprising in light of the text's cursory treatment of the fundamentals of measurement. In the future, it is important that the relevant unit conversions be sufficiently emphasized, both in the script itself and in appropriate overlays.

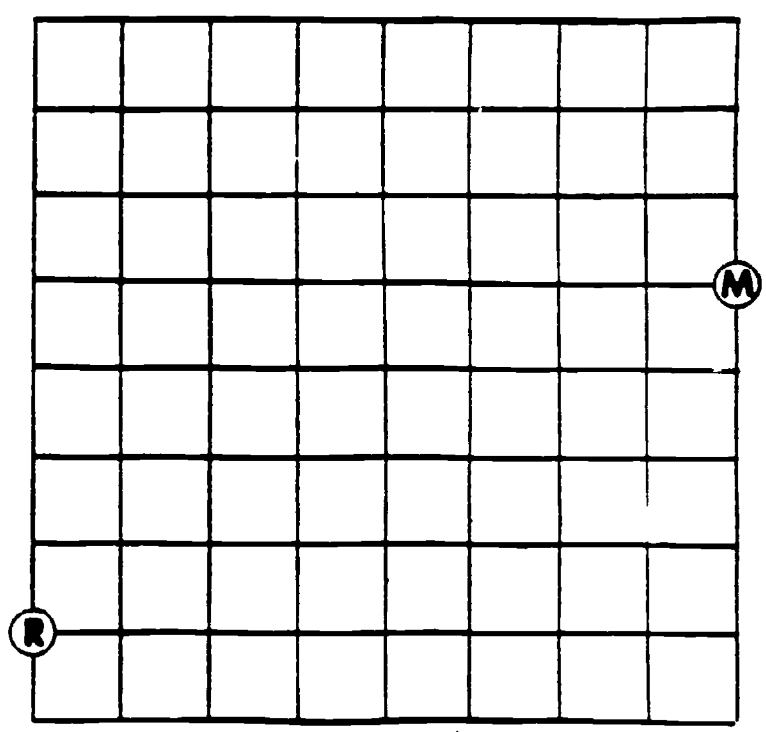
Description

Using a grid of the area, two knights try to figure out all of the possible meeting points halfway between their castles in order to avoid having to go out and fight a duel.

Mathematical content

This sketch is designed as an introduction to "taxi geometry" -- a geometry in which the distance between two points is defined as the sum of the usual horizontal and vertical distances between them. In this particular case, (see Figure 10) the distance between the castles of Sir Ron (R) and Sir Mike (M) is 12 units (8 units horizontally plus 4 units vertically). The story shows that taxi geometry is unlike Euclidean geometry in that two points do not always determine a unique midpoint. Another surprise is that the set of all points equidistant from M and R is not a straight line, as it would be in ordinary plane geometry, but is bent instead.

Figure 10
Grid Used in Interview



Relevant school experience

Taxi geometry *per se* is not treated at any level. All geometric ideas in the text series are based on Euclidean geometry, but all the prerequisites for understanding taxi geometry (simple linear measurement and counting) appear well before third grade.

Summary of results

Recall

When asked what problem Sir Mike and Sir Ron were trying to solve, all of the children recalled that they were trying to find places to fight that were halfway between the two castles. One third grader explained the problem as "where they were going to meet for the fight..they each had to have the same amount of steps to meet halfway." In terms of solution process, most children recalled that Lady Diane and the knights counted blocks to figure out ual distances and put markers on each of the possible meeting points. One typical response came from a fifth grader who said, "They had checkers and there was a big chart, and they had two castles. They were counting blocks so they could meet the same, and she [Lady Diane] put a checker right in the center."

All but one third grader recalled the solution to Sir Ron's and Sir Mike's problem, i.e., that they found many different meeting place. that were equidistant from the two castles. Most were also able to recall and draw the pattern that all the possible meeting points made on the grid. In the discussion of problem solution, one fifth grader described the knights' true motives for the exercise. He said, "They found about nine meeting places. The

Lady Queen, she had five points and then the knights, I guess they didn't want to fight or something. They just kept adding more meeting points on the map, so they could stall...I guess they were afraid."

Six weeks later, 9 of the 11 children questioned recalled that the knights were trying to find meeting places to fight. Eight of these mentioned that they wanted to meet halfway; as one fourth grader explained, "They tried to find different points -- every point they could find that was equally measured." A few children also recalled that Lady Diane used a "board" and "checkers" to find these meeting places, and that they counted six blocks.

Understanding

To measure understanding of Lady Diane's use of the grid, children were shown a Polaroid picture of the grid and asked what it represented. Almost all understood that the grid represented the area between the two castles, although some did not specifically refer to it as the village or town, but rather as the "forest" or "land" where the two knights could fight. Fewer children, however, understood that the lines of the grid represented streets or blocks in the town. This became important when the children were asked to demonstrate how Lady Diane and the knights counted the blocks to find possible meeting places. Some of the children did not count the intersections to determine the number of blocks, but instead counted the squares on the grid, which led to some miscounting and confusion.

One of the constraints in the problem of finding meeting places was that the knights were supposed to travel only along direct routes. In recalling the storyline and relevant mathematical information, no child mentioned this particular fact. Later in the interview, they were asked to define "direct route" and to identify the direct route in two examples of possible routes to travel. A few children showed partial understanding of what it meant to travel on a direct route, describing it as going the "short way" or going "without a lot of turns," and some correctly identified the example given. Most, however, confused it with going halfway or with walking on the streets versus cutting through the blocks. They clearly did not know what the phrase means and how it was being used in the segment. This misconception resurfaced later in the interview when children were asked to count blocks as the characters in the segment did. Some children made the mistake of not counting along a direct route.

A number of the interview questions focused on the issue of correctly counting blocks to find appropriate meeting places. For example, children were given a map like the one used in the segment and asked to put an "X" on a place where Sir Ron and Sir Mike could meet. Only half were able to do this sucessfully, counting line segments and following the rules laid out in the sketch. Children were then shown a map with an X at a point four blocks away from Sir Ron and eight blocks away from Sir Mike, and asked if the two knights could meet there. Here every child correctly claimed that they could not. As one fifth grader said, "No, because it's not halfway. Sir Mike's is much longer and Sir

Ron's is much shorter. They had to walk the same amount of blocks." Similarly, almost all of the children correctly argued that the knights could not follow a path that cut diagonally through one of the blocks. A typical response came from a fifth grader, who said, "He was supposed to walk block by block, but instead he went through the block." In contrast to the recall and understanding of the "direct route" rule, almost all of the children across the grades clearly understood the rules requiring the knights to meet halfway and not to cut through the blocks.

Another "U" question probed for some understanding of the mathematical principle of traveling along a grid. The children were shown a grid with two different routes outlined, each six blocks long, each ending at the same intersection. They were asked, "Sir Mike could go this way to this point and meet Sir Ron and it's six units. Or, Sir Mike could go this way and it's six units. Why is it always six units?" No one was able to give a full explanation of this principle, by saying, for example, that every shortest path between the two points involves going two blocks west and four blocks south regardless of the order in which the blocks are traversed.

In the final understanding question, children were each given a grid or map and asked to put an X on all the places they could end up if they were to travel a distance of three units. At least two children from each of the three higher grades successfully plotted all the points, forming a square on the grid. A few others came very close, missing at most three possible intersections.

Extension

The first extension question asked what shape these plotted points made. Most of the children in fourth, fifth, and sixth grades identified the pattern as a square.

The next extension questions required children to work with a new, blank map (without a grid). They were told that Sir Mike and Sir Ron were now in the desert where there are no streets, and asked to put a dot at places where they could meet so that neither one walks further than the other. All but one child located at least two possible meeting points. Approaches to this extension question varied. Some children measured with their pencils to find halfway points; others intuitively sensed what would be equidistant from the two castles. No child, however, had the insight that all the possible points would form a line running diagonally across the page (the perpendicular bisector of the segment joining the two castles).

Perceptions

Almost all of the children had positive perceptions of Sir Ron and Sir Mike. When asked how they knew that the knights felt this way, many children focused on their physical actions -- the fact that at the end of the sketch they were both smiling and putting their arms around each other. Other children felt the knights were happy because they didn't have to fight, because they were now friends, or because they had found many meeting places.

Of the 24 children, 22 indicated that Lady Diane felt happy. Their reasons included that she figured out the problem, that Sir Ron and Sir Mike were now friends, and that the duel had been avoided. As one sixth grader said, "She was happy because she knew that they weren't going to have to fight, 'cuz they were so happy and they were friends now." Many children also mentioned that she was smiling and laughing at the end of the segment.

When asked if there was any mathematics in the segment, all but four children responded affirmatively. The most common description of the mathematics was "counting blocks." Other children mentioned 6+6, specifically. Many children also said incorrectly that division was used in the segment, probably in reference to dividing the space between the castles in half.

Discussion and formative implications

Interpretation of the results of the interviews on this segment must be made with the realization that taxi geometry is a topic totally unfamiliar to the audience. Nonetheless, the children had good recall of the problem statement, solution, and solution process. Understanding of the unfamiliar mathematics in the piece was not as solid. Only half of the children interviewed were able to count blocks correctly, following the rules laid out in the segment. Most children also demonstrated that they did not know what "direct route" means or how it was used in the segment. In addition, it was not clear to many of them that the lines on the grid represented streets, and, in turn, that the characters in the segment were counting line segments (not the squares themselves). In short, most children did not have a firm grasp of the mechanics of this unfamiliar representational system; indeed, the children's intuitions were dominated by the Euclidean framework.

In future segments about taxi geometry, the rules for determining the distance between two points on the grid should be laid out more explicitly for the children to understand clearly the constraints involved in the problem. The idea of "direct route," for example, could be illustrated more thoroughly, with examples of both direct and indirect routes. Similarly, it should be made clear that line segments, and not the squares, are counted. For example, the characters could gesture and trace the line segment from one intersection point to the next, and the path might be highlighted electronically.

"IN SEARCH OF THE GIANT SQUID"

Description

The navigator of a submarine fails to consider the concept of scale, and mistakenly thinks that an iceberg is centimeters, instead of kilometers, away.

Mathematical content

The mathematics in this sketch is a straightforward application of scale. A measurement made on a map is transformed, via a scale factor, into a distance in reality.

Relevant school experience

The units of measurement used in the Addison-Wesley series are principally metric. Customary units are used as well, but at all grade levels they are treated very late in the text, where many children may not be exposed to them. The meter and the kilometer are introduced in the second grade, and the centimeter is presented even earlier. Few lessons are devoted to linear measurement, but, in all four texts the greatest emphasis is placed on centimeters.

The idea of scale drawing first appears in one lesson in the latter part of the fifth-grade text. The sixth-grade book includes two pages on the topic, presented in connection with ratio. In neither case is the lesson concerned with maps. It is likely, however, that most children will have been exposed to scale in connection with maps in their study of geography.

Summary of responses

Recall

All of the children were able to recall and identify the problem, namely that the crew had to figure out how far away the iceberg actually was from the ship. One fifth grader explained that "On the map, it was 10 centimeters; [they had to] find out how far it is in reality." A third grader said, "He thought the iceberg was 10 centimeters away from the ship, [but] it was farther." All of the children also recalled at least one of the steps involved in solving the problem. Many remembered that they "used a ruler," "measured on a map," or, as one fifth grader said, "They multiplied 10 x 10 to find actual distance from the ship." Similarly, all but one of the children were able to recall the solution to the problem -- that the iceberg was not close by, but far away. A few children even remembered its exact distance from the ship (100 kilometers).

When asked six weeks later what happened in the segment, 5 of the 12 children recalled that the characters were trying to figure out how far away the iceberg was. As one fifth grader stated, "They were trying to figure out how far the iceberg was from the ship. The guy thought the iceberg would hit the ship, but it was far away." Other children remembered just that the iceberg was farther away than they initially thought. In terms of process of solution, two children recalled that they "measured with a ruler," and another two remembered that they "timesed" 10 x 10 to figure out how far away the iceberg actually was.

Understanding

In discussions about the problem, the solution, and the solution process, only one sixth grader referred specifically to scale, saying, "They made a key scale...I think it was 10 centimeters equals so many kilometers...to figure out how far it was." However, later in the interview when children were asked to define scale, most evinced partial understanding of the concept. Younger children tended to define it in terms of its use, saying, for example, that it "measures the distance of miles on the land or on the sea" (a fourth grader) or that it "tells how far wherever they are going is" (a third grader).

Older children demonstrated a more sophisticated understanding of representation. For example, one sixth grader explained, "When you have a ruler, you measure the distance to the iceberg..but [they] had to find out the real distance, not what's on the ruler." Another said, "You take either centimeters or something like that, and decide how much that'll represent in the real seas.... So like if this much on a ruler represents 10 kilometers on a map, you find out how much apart something is."

One third grader grasped the concept of scale and its purpose without actually connecting it to the word "scale." When asked how the crew members figured out how far away the iceberg was, he responded, "They multiplied 10 x 10...on a map it is much smaller than it is in real life. If they make it as big as the whole world, you'd have another world." Presumably, he was using the explanation of the function of scale given by the captain, who explains that without scale, a map of New Jersey would have to be the size of New Jersey.

Other understanding questions focused on measurement. Children were asked to draw a line about 1 cm long. Almost every child was able to draw a line of approximately this length, somewhere in the range of .5 cm to 2 cm. None of the children, however, challenged the interviewer on the next (trick) question which asked them to draw a line about 1 kilometer long. While all drew a line longer than their centimeter line, and a few registered some surprise at the question, not one child conclusively stated that a kilometer is too big to draw on a piece of paper. To compare these responses, some of the children were then asked to draw a mile. Here, one sixth grader immediately said, "A mile! It won't fit on the paper," and others drew lines significantly bigger than the kilometer line, either drawing them running off the page or running continously up and down the page. In general, this suggests that the children's understanding of the length of a kilometer is not solid, especially when compared to their understanding of a mile. In the case of at least one child, this lack of knowledge led to some misconceptions about the basic plot of the segment. When asked what the solution to the problem was, one sixth grader explained that they "put the ship the other way." In other words, this child still believed that the submarine was in danger even though it was kilometers away from the iceberg, and that the crew had to turn the ship around to avoid a collision.

Other questions also revealed some confusion and lack of knowledge about metric measurement. Only one child was able to say how many meters are in a kilometer. Similarly, when asked to line up five cards (labelled "1 centimeter," "1 inch," "1 foot," "1 meter," and "1 kilometer") in order from smallest to biggest, only one sixth grader could order them correctly. In a few cases, the only mistake was putting an inch before a centimeter; in most cases, however, the misconceptions were more extensive. For example, some of the children put all of the metric measurements before the standard measurements in this order: 1 centimeter, 1 kilometer, 1 meter, 1 inch, 1 foot. A sixth-grade child put kilometer <u>first</u>, followed by centimeter, meter, inch, foot. While these kinds of mistakes were made across the grades, not one child made the mistake of putting a foot before an inch.

Extension

For the extension questions, each child was given an activity sheet similiar to the map used in the segment; on each, there was a triangle representing an iceberg and an X representing the ship. The scale, 1 cm : 10 km, was printed on the bottom of each sheet. Children were given centimeter rulers and asked: On the high seas, how far is your ship from the iceberg? While none of the third graders were able to answer this question, almost half of the older children successfully used the scale and arrived at the correct solution.

They were then asked the following question: A shark is 190 kilometers away from your ship. How far would that be on your map? Again, a few children from the fourth, fifth, and sixth grades answered the problem correctly. Some of them did not fully articulate how they got their answers and seemed to have a more intuitive understanding of the problem. Others, however, were able to explain the process they used to arrive at their answers. For example, when asked how he got his answer, one fourth grader explained, "because 10 19's go into 190; 1 centimeter equals 10 kilometers. So 10 times something would equal 190."

In the final extension question, each child was given a centimeter ruler and asked to put a dot 7 centimeters away from the ship. A little more than half were able to measure correctly. Those who did not usually made the mistake of starting from the 1 cm mark on their rulers rather than from zero. After finding one point, they were asked to find all of the points or places the ship could go that are 7 centimeters away. Here, almost all the children across the grades marked off a number of points and then correctly concluded that the answer was a full circle around the ship's starting point. The most sophisticated response came from a sixth grader who, when asked this question, immediately recognized that it would be a circle and said, "It would be easier to just take a compass and do it.... You'd get the whole circle if you took a compass and put the one end here and the pencil here. As it turns its going to stay 7 centimeters away the whole time around."

Perceptions

All of the children's perceptions of the navigator were positive. Most focused on the fact that he "figured out" or solved the problem. One third grader explained, "He felt good about himself." Another fifth grader said that he felt very good because, "he knew how to measure with a centimeter ruler over the high seas." Most of the children also perceived the captain positively, either because he solved the problem or because he had managed to avoid hitting the iceberg. In explaining how they knew that the characters felt this way, many children mentioned physical reactions (smiling, hugging).

All of the chidren said that there was mathematics in the segment. Many children referred to "10 x 10," one of the calculations performed in the conversion of centimeters to kilometers. Other children mentioned measuring, using a "centimeter" or metric ruler, or using a map. One group of sixth graders explained that they were "converting one centimeter to ten kilometers...to get how far the distance really was away." No child directly mentioned the use of scale.

Discussion and formative implications

In sum, children recalled the problem, problem solution, and solution process. Their understanding of the mathematical concepts introduced in the piece varied. While the notion of scale seemed to be difficult for most of the children, many did demonstrate some understanding of at least its function; some of the older children could also define it more fully, in terms of one distance representing another. In contrast, the questions about metric measurement revealed that almost all of the children had no understanding of the length of a kilometer: when asked to draw a line 1 kilometer long, many children drew a line a few inches long. (This finding is compatible with the extent of coverage of metric units in the Addison-Wesley text series.)

In this segment, the combination of two relatively unfamiliar topics -- kilometer and scale -- raises some implications for Season II. It is possible that, in combining these topics, misconceptions about one of them might lead to misconceptions about the other. In this case, since children tend to talk about scale in terms of equivalence (1 cm <u>equals</u> 10 km) rather than representation (1 cm <u>stands for</u> 10 km) their lack of knowledge about kilometers might lead them to the misconception that 1 cm is the same length as 10 km.

In general, presentations of metric measurement might be clearer if the units are given a frame of reference in the real world. In this case, for example, the captain of the submarine might have made some exclamation about how "big" a kilometer is, connecting it in some way to a distance familiar to a child.

"PHOTOGRAPH ALL ABOUT IT"

Segment description

The Predictors must predict who will be elected governor. In doing so, they determine all the possible orders for finishing if there are two, three, or four candidates. They use photographs to illustrate how the number of possible outcomes can be determined.

Mathematical content

At one level the goal of this sketch is to determine the number of ways in which a set of three (and then four) distinct objects can be ordered -- a technique often useful in combinatorial situations. At a higher level it suggests the more general inductive idea that one can approach a problem (e.g. the number of orderings of four objects) by building upon a previously considered case (three objects).

Relevant school experience

The kind of combinatorial problem presented in this sketch never appears in the Addison-Wesley elementary texts, although the multiplication computation involved should be familiar to all the children. (Even the 5 x 24 calculation in the extension question dealing with the number of orderings of five distinct objects is treated in the third-grade book, though fairly late).

Summary of results

Recall

All of the children recalled that the Predictors were trying to predict who would win the race for governor and which candidates would come in first, second, third, and fourth. Furthermore, all of the fifth graders also recalled the mathematical problem at hand: the Predictors must determine all the possible orders in which two, three, and ultimately four candidates could come in. One third grader described the problem as "how many ways they could put the people in order." When asked how the Predictors figured this out, almost all of them remembered that they "multiplied" and the third-grade girls recalled the mathematics exactly. As one child explained, "They multiplied, kept on multiplied [sic], 6 x 4 = 24 and 1 x 2 x 3 x 4 = 24." Futhermore, most of the children were able to recall the Predictors' mathematical solutions --how many different ways two, three, or four candidates could finish in the election.

Six weeks later, when asked again to recall what happened in the sketch, 5 out of 12 children remembered that the Predictors were trying to figure out who was going to win an election. As one fifth grader explained, "They had to figure out who was going to win the election. They had a lot of problems because more people kept entering the race." Two children also mentioned that there were "24 ways that they could do it."

Understanding

Understanding of the mathematical content in the sketch varied. When asked how many different ways candidates X, Y, and Z could finish in an election, all of the third graders correctly responded, "six." Two of them arrived at the answer by writing down all the possible orders. Another two explained that they "remembered it from the show." The third-grade girls applied the mathematics in the sketch; when asked how they knew they had all the possible orders, they used the multiplication method to justify their results (i.e., 2 x 3 = 6).

Some of the fourth and all of the fifth graders approached the problem in a similar way, making lists of the possible orders and checking their work to make sure they had them all and that they had no repeated combinations. The fifth-grade girls used a systematic approach to check their work, by first noting all possible orders with Y in first place (YXZ, YZX) and then doing the same with X and Z. One child explained her actions, saying that "X, Y, and Z could come in first, second, or third."

In contrast, one group of sixth graders immediately got the correct answer, explaining that "When they had three pictures [in the segment], they said there were six possible orders." They were also able to explain why this was the case; as one child said, "...three letters and each comes first once. It's two times for each that's first. 2 x 3=6."

Children were also probed for their understanding of how the Predictors used pictures of each of the candidates (Cynthia, Chris, Arthur, and Reggie) to illustrate different possible orders. In one question, three cards, labeled "Cynthia," "Arthur," and "Chris" were placed on a board in that order. The children were then asked, "If I put the pictures like this, who won the race?" All of the children correctly answered "Cynthia." The next question focused on a specific action in the segment: when Reggie, the fourth candidate, entered the race, one of the Predictors took the photograph of him and placed it briefly on four successive spots, the two spaces between the three photographs already on the board, and the two spaces on the extreme left and right. This was done to illustrate all the possible places Reggie could come in by showing that Reggie could be placed in any of four ways for each particular arrangement of Cynthia, Arthur, and Chris.

The children were asked to demonstrate, using cards and a board, what the Predictors did to figure out where Reggie could go. While all of the sixth graders correctly imitated the Predictors' placement of the photo of Reggie in the spaces <u>in front of</u>, <u>between</u>, and <u>following</u> the other photos, none of the other children did. Instead, they tended to place Reggie's card <u>on top of</u> those of the other candidates. This misconception effectively obscures the connection between the number of arrangements of one set of objects and the possibilities for the next larger set.

<u>Extension</u>

To test their ability to extend the mathematics, children were asked how many different ways <u>five</u> candidates could be arranged. About one fourth of the children got the correct answer, 120, by multiplying 24 x 5. The group of third-grade girls all immediately understood that the answer would be 24 x 5; the only difficulty for them was the actual multiplication, which they ultimately figured out by adding five 24's together. In the other groups, those children who did not get the right answer usually had one of two misconceptions. Some thought the answer was 5 x 5 because, as one child explained, "There are five different people and five places." Others made the mistake of adding, instead of multiplying five, and 24; they reasoned that with four candidates the answer was 24, and the fifth candidate could come in either first, second, third, fourth, or fifth, thereby creating five more possible orders.

The final extension question asked how many four-digit numbers could be made from these four digits: 3,7,7,8. This proved challenging to all. Most children in the third, fourth, and fifth grades made a list of all possible combinations, usually skipping or repeating at least one and therefore getting an incorrect answer close to the correct one. A few also became confused by all the numbers involved. Instead of treating the numbers as separate units to be arranged in different orders, they often tried to multiply or add 3,7,7, and 8 together. Most of the sixth graders, however, were able to do the problem by making systematic lists of all the possibilities and checking their work.

Perceptions

Children were asked how the Predictors felt at the end of the story. In sharp contrast to the other nine segments tested, only six children responded positively. Most described the characters as "worried," "nervous," "bad," "upset," or "mad." The most common explanation of this was that they were going to lose their jobs. For example, one fifth grader said that they felt "nervous, because more people kept on adding on and if they didn't get it finished, they would go out of business." Another child explained that the man felt bad because he "didn't know the answer." Childrens' explanations refered to the fact that the problem was not solved.

All of the children recognized that there was mathematics in the sketch. Every child specifically mentioned multiplication.

Discussion and formative implications

In summary, recall of relevant problem solving and mathematical information was high for this segment. Many of the children also understood the mathematics, although the process through which the number of orderings was determined was difficult to understand. In some cases they successfully extended the mathematics to a new problem. The third-grade girls were particularly sophisticated in their responses. This overall performance seems remarkably good in light of children's limited exposure to combinatorial situations in their formal schooling.

It is evident from the perceptions questions that some children were sensitive to the fact that the Predictors do not actually solve the real problem at hand, namely who is going to come in first in the election. Because of this, there is not the usual, positive perception of the problem solver as eitner having demonstrated competence or as having benefited from solving a mathematical problem.

Looking to formative implications, it is clear that most of the children did not understand that the Predictors placed the photo of Reggie in front of, between, and following the other photos, in order to demonstrate all the possible places Reggie could come in. Perhaps this is simply because it is easier to count objects (the photos) than the intervening spaces. Alternatively, they may have been misled by the numerals above the photos already on the board that initially indicated the first, second, third, and fourth places, but that, with the addition of Reggie, were no longer relevant. The numerals' fixed positions may have conveyed the incorrect idea that the rank of each candidate is unaffected by the insertion of Reggie. In retrospect, it may have been better not to have had any numbers on the board, or at least to have had numbers that could be moved when the photos were moved.

"CALLOUS -- THE SURVEY"

Description

J.B. Callous and his family conduct a survey to find out why Callous Candy Gumdrop sales are so low in their hometown of Grasshopper Gulch.

Mathematical content

The main mathematical aim of this sketch is to introduce the idea of a statistical sample -- in this case a group of people who are somehow representative of a larger group whose opinions are of interest. A subsidiary objective is to show how data can be presented through bar and circle charts, both of which use percents.

Relevant school experience

Bar graphs -- both their construction and interpretation -- are introduced in the third grade Addison-Wesley text, and circle graphs appear in the fourth grade (although circle graphs using percents are delayed until fifth). While the texts provide examples of interpreting data that are to be gathered as a class project, the idea of a survey -- that is, making inferences about a larger population based on data from a subset -- does not appear.

Summary of responses

Recall

All but one of the children recalled the problem that Sue Becky, Becky Sue, and J.B. Callous were trying to solve in the sketch--

why gumdrop sales were lower in Grasshopper Gulch than in other cities. The exception, a fourth-grade girl, stated that the Callous family was trying to "solve the problem of gumdrops being too sugary" (but note that this is the problem that the Callous family has to solve at the end of the sketch). In addition, all of the children also remembered J.B.'s proposed solution to the problem -- the production of sugar-free gumdrops.

When asked how the Callous family figured out how to solve the problem, half of the children mentioned that they took a survey, although most described it as "interviewing people" or "asking a lot of people" about the gumdrops. For example, one third grader explained that "Becky Sue interviewed people and she put down how many people liked and didn't like the gumdrops." In addition, most recalled that they used a bar graph or pie chart to figure out the solution to the problem. As one fifth grader said, "[they] made a pie graph: 58% said it was too sugary, 8% said it didn't stick to the screen, 6% didn't like the box."

Children were also asked to recall the information about survey sampling. Almost all of the children recalled Sue Becky's response to Becky Sue's survey of the Women's Sewing Circle. These children either paraphrased Sue Becky's comment that "14 people of the sewing circle are not representative of town opinion," or said that the sewing circle was not a fair sample because it did not include men or children. (No one mentioned the sewing circle's possible bias against square boxes, which would have been another acceptable response.)

When children were asked, six weeks later, what happened in "Callous," 9 out of 10 were able to recall the essence of the problem -- that the gumdrops were not selling. Six children explained that people were not buying the gumdrops, while three children mentioned that J.B. wanted to know why his gumdrops were not selling. As one sixth grader said, "[J.B.] wanted to see what was wrong with the candy and why wasn't it selling." Seven children specifically mentioned either the graph, chart, or survey in their discussions of the solution process. A few children included specific numbers, such as the fourth grader who said, "50% liked it one way and 20 and 30 liked the different way."

Understanding

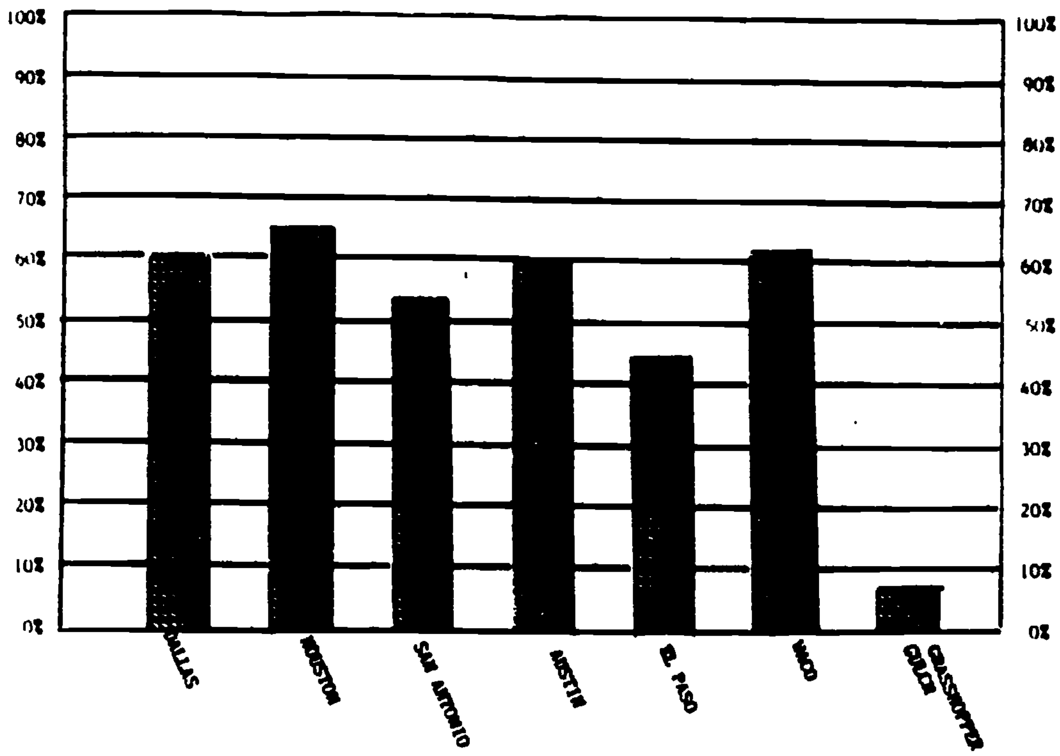
Children were tested for their understanding of subject pools. They were asked why the Callous family did not survey just one man, one woman, and one child. All of the sixth graders and most of the rest of the children answered this question correctly, explaining that a very small sample might not be representative of an entire group. One fifth grader said, "Different people have different tastes. So if they just asked one woman, man, and child, other people would not like them the way they like them." Other responses were incorrect for different reasons. One fourth grader thought it was not a good idea because "all of the other men, women, and children would ask, 'Why didn't you pick me?'" Another fourth grader thought they could have asked just one man, one woman, and one child, because "maybe a kid knows more about jelly beans."

Most children correctly recalled that the Callous family did not ask everybody in Grasshopper Gulch to be in their survey. Only half of these children, however, were able to explain why this was so. Two third graders gave typical correct responses. One child said, "There's too much people." Another explained that the survey "might take too long." Many children who answered incorrectly brought up possibilities that were not directly related to the problem. For example, one third grader said, "Maybe they knew some people and she knew they wouldn't like the gumdrops." A fourth grader speculated that the surveyors would "get all mixed up" and "couldn't keep track."

A series of questions were designed to probe for children's knowledge of percent and their understanding of the pie and bar charts used to depict survey results. While most of the sixth graders were able to describe percent adequately, most of the younger children gave mid-level or totally unacceptable responses. For example, one third grader said, "It's like how many people did a certain thing or thought a certain thing." A fifth grader explained, "Say you have 40 pencils. Take 3% away. I don't know what percent means." Most of the children, however, who inadequately described percent recognized that 45% is less than one half, demonstrating at least some familiarity with the concept of percentages.

When shown a graphic representation of the pie and bar charts, half of the third and fourth graders and all of the fifth and sixth graders correctly identified the pie chart, and, with the exception of the third-grade boys, all children correctly identified the bar chart. (See Figure 11.) All of the children across the grades were able to read the information depicted on both charts, (for example, that 60% of the people in Dallas buy Callous Candy Gum Drops).

Figure 11
Bar Chart Used in Interview



The children were then asked what they thought all the numbers on the pie chart would add up to. About half of the fifth and sixth graders and a few of the third and fourth graders reported that the sum of the numbers, or percentages, on the "Callous" pie chart is 100%. The other children used pencil and paper to calculate the sum. These children did not seem to know that this pie chart is a graphic representation of the parts of 100%.

Extension

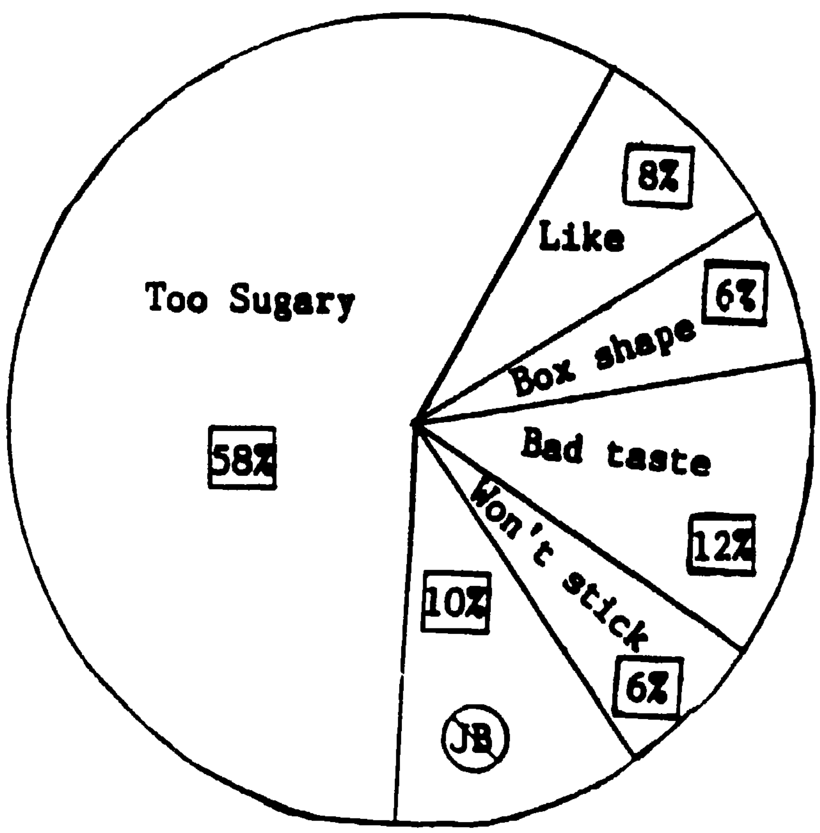
One of the extension questions probed for children's realization that certain information was not contained in the bar chart. Although the chart only presented data about sales percentages in various cities in Texas, children were given a "trick" question that asked them to determine which of two cities has more people. Even though the bar chart did not provide information about the total population of the cities, many children in the third through fifth grades thought that whichever city showed the higher bar had more people.

Finally, the children were asked what would happen if J.B. changed the gumdrop characteristics that people did not like. For example, the pie chart of survey results shows that 58% of the people thought the gumdrops were too sugary. The children were asked, "What do you think will happen if J.B. Callous changes the gumdrops so that they don't have the sugar, but everything else about them stays the same?" About one half of the children explained that people who previously did not buy the gumdrops because they were too sugary would now buy them. Other children discussed how changing the sugar content might also change the taste, and that consequently it is impossible to predict how this change would affect sales. Some children were more specific. They discussed how changing the sugar content might change the stickiness, and how the people who were concerned about stickiness might change their buying habits. In some cases, they then related their discussions back to the pie chart. For example, one fifth grader explained that if J.B.

Callous makes the gumdrops sugarless, "...66% will like them, because 8% like it already plus 58% would be 66%."

Similarly, the children were asked what would happen if they changed the shape of the box. Most of the children added the 6% (who did not buy the gumdrops because of the box shape) to the 8% (who already liked the gumdrops). (See Figure 12.) One third grader stated, "They'll buy more--they like circle boxes." Two fifth graders and one sixth grader discussed how the product would be the same even if the shape of the box changed. Some children also spoke about the percentage change if the sugar content was changed in conjunction with the change in box shape.

Figure 12
Pie Chart Used in Interview



Perceptions

When asked how Becky Sue and Sue Becky felt when they solved the problem, all children described them in positive terms. About half of the children attributed the characters' feelings to getting more money or selling more gumdrops, and several said Sue Becky and Becky Sue were pleased because they figured out the problem.

Twenty-two children perceived J.B. positively, most describing him as happy because of monetary rewards. Several children referred to J.B.'s smiling and his having solved the problem. A fourth grader said J.B. was "excited" because "they finally found a solution why his gumdrops weren't selling," and "his business wouldn't go down." The only negative responses came from two fourth-grade boys who said J.B. was "embarrassed." One of the boys explained this conclusion by saying, "He felt embarrassed, 'cuz the woman solved it, and he didn't."

Almost all of the 24 children said mathematics was used in the segment, many of them giving several examples. Most children mentioned the pie chart and bar graph. Others referred to mathematical activities such as adding and tallying.

Discussion and formative implications

Across the grades, children had good recall of the problem statement and solution. When asked about solution process, most of the children recalled that the Callous family did a survey, although many of them referred to it as "interviewing" or "asking" people about the gumdrops.

Almost all of the children also mentioned that they used a pie chart or bar chart to solve the problem, and all of them demonstrated an understanding of how to read these charts. When further questioned, however, the younger children revealed a lack of knowledge about percents. Both of these findings are consistent with their school experience; in the Addison-Wesley text books, bar charts are introduced in the third grade, circle graphs appear in the fourth grade, and percents are delayed until fifth.

Other understanding questions focused on sample size. Most of the children could explain why the Callous family did not interview just one man, one woman, and one child. Yet, only half appeared to understand why they did not ask <u>everybody</u> in Grasshopper Gulch. Future segments on this topic could include a more complete explanation of what is a reasonable sample size for a survey such as this one.

The extension questions proposed different changes to the candy. In general, they yielded some detailed and involved discussion about marketing concepts. In some cases, the children related their ideas back to the pie chart, reading and adding percentages, in order to determine the exact increase or decrease in potential buyers. Even third graders used the chart and offered correct ideas. This piece was successful in eliciting insightful discussions about product change, adding percentages, and buying habits.

"BUT WHO'S MULTIPLYING?"

Segment description

Two child contestants attempt to cover three numbers in a row (either vertically, diagonally, or horizontally) on the Product Board by selecting factors of these numbers from the Factor Board and calling out the resulting product. The first player to cover three in a row wins the game.

Mathematical content

"But Who's Multiplying?" is a typical SQUARE ONE TV game in that it invites participation at many mathematical levels. For younger children the aim is to apply knowledge of single-digit factors and their products to build simple geometric configurations, while older children may devise increasingly complex offensive and defensive strategies.

Relevant school experience

The kinds of multiplication calculations (one-digit by one-digit) that are required to play "But Who's Multiplying?" are the subject of seemingly endless drill and practice starting in second grade. Third grade is a year of particular emphasis on the multiplication "facts" in which both factors are greater than five, and of course children's fluency with these facts can be expected to increase in subsequent years. The strategic thinking needed to play the game effectively, on the other hand, is rarely given much emphasis in any elementary mathematics program -- certainly not in the series used by the participating children.

Summary of results

Recall and understanding

In order to find out whether children understood the game objective in "But Who's Multiplying?" before their responses could be affected by their peers, each child was given a piece of paper with six "game boards" immediately following viewing. They were then asked to circle the game boards that had winning configurations and cross out the game boards that did not. Almost all of the children responded with complete accuracy. The remaining four children gave one or two incorrect responses. In general, their independent understandings were very good.

It was clear that all of the children understood how to create specific products using factors on the Factor Board. They were also tested for their recall and understanding of the game and its rules through interview questions and three rounds of actual game play. Researchers asked two children in each triad to become "contestants" and the third to become the "game show host," whose job it was to explain the game rules and get the game going. During each round, all of the children demonstrated an ability to play the game. They understood that they needed to take turns and create three-in-a-row winning patterns, and that those patterns could be vertical, horizontal, or diagonal.

While playing, children often coached one another and restated rules. They remembered the 15-second time limit for responding on a move and imposed time limits on each other. As one fourth grader explained, "If it's too late, the buzzer goes off. If it's wrong, the horn goes off!" Another fourth-grade child, acting as the game show host, imitated the game's penalty sound effect and said, "You took a little too long. You go, Jeffrey." At the conclusion of another game, one of the players declared "We have a winner!" Similarly, a sixth-grade host said "Time is up. You took more than 15 seconds. Give the turn to Charlene."

Other children imposed game penalties on <u>themselves</u>, as one fourth-grade girl did when she chose factors whose product was already covered: "It's already covered up. I lose my turn." One of her peers responded similarly at another point during play, "It should be <u>her</u> turn. I messed it up. It's already called."

Although all children understood how to play the game, a few children in each age group forgot or did not know that they could move only their own color, <u>not</u> either color. Similarly, children in the third and fifth grades sometimes moved both rings on the factor board for each turn instead of just their own. In some instances, an entire game was played before the "host" or a contestant caught the error. Moving both rings for each play made the game play arbitrary; it removed the strategy involved in finding a combination of factors on the factor board that would also help win the game. Yet, the children did not seem to notice or mind.

Six weeks later, when children were asked what they remembered about the segment, all of the children recalled that it was a game, and 2 of 11 indicated that the name of the game was "But Who's Multiplying?" In their responses, most mentioned that the game required multiplication; for example a typical response from a sixth grader was, "...You have to multiply two numbers and you get a number on the board." In terms of the rules of the game, different children recalled different details. Across all of the interviews, however, four children mentioned the two players were red and blue, two explained that the bell would ring if the number chosen had already been picked, and at least one child recalled that you could only move your own color and that you had 15 seconds in which to make your move. In addition, most of the children remembered how to win the game: as one child explained, "You make three in a row, diagonally, horizontally, or vertically."

<u>Extension</u>

In extending the game, children were asked why the number 22 did not appear on the game board. With the exception of two third-grade boys, all of the children correctly explained that there was no way to create the product 22 by multiplying any two numbers from the set of numbers one through nine on the Factor Board. The two third graders started to explain the missing number, saying "They left the odds out, no the evens," and concluded that they did not know why it had been left out.

All of the children also correctly answered an extension question in which they were asked to create a "better move" than a particular move made in the segment. The researchers replicated a series of plays from the segment, and then asked what should have been done instead. The high number of correct responses demonstrates a good understanding of game strategy.

On a more difficult extension question, fifth and sixth graders typically performed at a more sophisticated level than third and fourth graders. For example, children were asked what a good first move would be. All but two of the fifth and sixth graders indicated that a move in the center of the game board would be a good one in that it provides many options for creating three-in-a-row patterns. Younger children often chose a move along the side or corner of the board, sometimes offering a defensive justification. For example, one fourth grader said, "Maybe for the edges, lots of opportunities to win...the corners." In contrast, one sixth-grade child offered this strategy: "Start in the center. Yeah, that's good strategy. Go out and all over, any way." Other sixth graders gave similar responses: "Try to take them in the middle, where you can go in all directions," and "[It's] not good to be in the corner; you could get blocked. Stay out of the corners."

A final extension question designed to isolate geometric strategy from the numerical distractions, showed children a blank game board, without numbers, factors, or rings. The children were asked who would win if red and blue took turns, red went first, and the goal was to get three in a row. Most children observed that the game was like "Tic-Tac-Toe." Two of the fifth graders offered full answers that described the possibilities which would ultimately lead to winning the game. All of the sixth graders and some of the younger children thought that red always wins (because red always goes first). A few children were able to describe a winning strategy.

Perceptions

Almost all of the children had very positive perceptions of how the child who won this version of "But Who's Multiplying?" felt at the end of the game. When asked to explain why the child felt "happy" or "excited," many attributed it to his victory. For example, one fourth grader said, "He won and he's happy. I'd be happy." A less typical response came from a sixth grader who said, "He felt confident," and two children who felt that he was happy because he had won the calculator prize.

In contrast, almost all children perceived the other child as "sad" at the game's finish. A few others described him as "disappointed" or "mad." Their explanations of this usually referred to either the player's facial expression or the fact that he had lost the game. One sixth grader said that he felt "sad, because his team was counting on him; they were all counting on him and they were disappointed because they didn't live up to their potential."

When asked if there was mathematics in the piece, all but three of the children responded affirmatively, describing the mathematics as multiplication. As one third grader said, "Yes, definitely...I think the whole game was made up of multiplication."

Discussion and formative implications

In summary, children enjoyed playing "But Who's Multiplying?" during testing sessions. Several children expressed dismay that they could not continue playing the game with the testing materials. In general, the children played with an understanding of how to create products using factors from the Factor Board. They also played strategically, trying to get three squares in a row and preventing their opponent from blocking them.

"But Who's Multiplying?" is successful in providing a motivational context for doing mathematics. Of course it provides practice with single-digit multiplication that schools typically stress. But, more importantly, it gives children of different age and ability levels the opportunity to devise strategies of varying degrees of sophistication.

In all grades, however, some children were confused during game play about how to use the rings. They were sometimes unsure whether players move their own ring, or whether they can move both of them. Some forgot their color during game play, or demonstrated confusion about which ring was their own. However, this confusion typically disappeared over repeated play. A new production of "But Who's Multiplying?" might emphasize the rules for how the rings are used in the game.

Another possible consideration arises from the perceptions findings. Clearly children in this age range have a good deal of experience with competitive games. And, perhaps because of their own experiences, they tend to perceive the "loser" in "But Who's Multiplying?" as being sad or mad, or as letting the team down. As a way of tapping into a different kind of experience, it might be beneficial to introduce some cooperative games into the series, where, for example, a team of children might work together against the clock or toward a common goal.

"KUBRICK'S RUBE"

Description of segment

In this parody of the film "2001, A Space Odyssey," astronauts Irving and Dave devise a looping program to get Hank the computer to stop singing "Row, Row, Row Your Boat."

Mathematical content

This sketch presents an example of a computer program containing an endless loop. The failure of the program to terminate rests on a simple parity idea: adding an even number to an odd number results in another odd number.

Relevant school experience

Odd and even numbers appear early in the third grade text, having been introduced in the second grade. The idea that is critical to the sketch -- namely that whenever an even number is added to an odd, the sum remains odd -- is not explicitly treated until fifth grade.

Summary of responses

The recall questions for "Kubrick's Rube" focused on problem statement, process of solution, and solution. When asked what the problem was that Dave and Irving were trying to solve, all of the children recalled that they were trying to stop the computer from singing. To test for recall of process solution, children were asked how Dave "figured out" how to stop Hank from singing. For their responses to be coded as "Y," children were required to recall that he created a program (they did not have to use this word *per se*) that looped or "did not end." Responses that referred only to program, and did not mention that the program would not stop, were coded as "M" (mid-level response). On this item, 20 of the 24 children questioned gave "Y"-level reponses, where two were coded "M", and another two "O". Seven of the children recalled that Dave created a "program"; others thought of it as a "problem." For example, one fifth grader said, "He put in a program that he will never stop," while a fourth grader explained, "They made a big, hard problem that kept going and going." A few of the younger children described it as "putting something into the computer."

Children were asked to recall what the solution was to Dave and Irving's problem -- what the program was that Hank, the computer, had to run. Here a "Y" level response required accurate recall of all three steps of the progam:

Step 1: START with three.

Step 2: ADD four.

Step 3: if the sum is even, STOP.
if not, go to STEP 2.

Only five children were able to recall all three steps accurately and in the correct order. A few of the children, however, had partial recall of the program and how it looped. For example, one third grader recalled step one as "Add four and three," step two as "Now add seven and four," and step three as "Keep on adding and try to get an even number; keep on going 'til it finds an even number." Another fifth-grade child said, "Step one, add two numbers together, step three, if you don't get an even number, go back to step two."

Six weeks later, most of the children remembered that they got the computer to stop singing, because "it never got an even number." A typical response came from a fifth grader who said, "The computer did stop. It stopped singing after [adding] odd and even numbers in it. They told it if he gets an even number, he could stop singing, but he never got an even number." Four children, however, did not remember what kind of numbers the computer was adding; they thought it was adding odd numbers together, instead of odd and even.

Understanding

The three understanding questions for "Kubrick's Rube" probed for children's understanding of how or why Dave's program looped. Familiarity with the concept of even numbers is central to any understanding of this. Therefore, children were asked: "What is an even number?" Eleven out of 24 were able to answer this question correctly; as one fourth grader explained, an even number is "...any number you can divide by two [with an integer quotient]." The rest either could not define the concept or else defined it incorrectly. For example, one child described even numbers as "counting by fours." Most of the children, however, could give several correct examples of even numbers.

Children were also tested for understanding of the idea that whenever an even number is added to an odd, the sum is odd. They were asked, "How come Hank will never reach an even number?" All but two of the fifth and sixth graders were able to explain why this was so. As one fifth grader said "...kept adding odd and even [numbers], comes out to an odd number." In contrast, no third graders and only two fourth graders evinced a full understanding of this idea.

Children were then asked the following question: "The last number we saw Hank get was 91. Will he stop now? [No]. Why or why not? Show me what he would do with 91." Here, one third grader had the misconception that Hank would stop after 91. The rest of the children understood that even though 91 was the last number on the screen, the looping program ensured that Hank would in fact keep going on and on. Only 14 out of the 24 children, however, were able to figure out that 95 would be the next number Hank would get. Across the grades, the children who did not get the correct answer usually added two, instead of four, to 91. Two others simply did not know what number to add. As one fifth grader said, "[the computer would] add another number, I don't know what number."

Extension

The first two extension questions proposed different modifications to Dave's program. First, the children were given a handout with Dave's program written on the top, and the following printed on the bottom:

Step 1 Start with ______

Step 2 Add ______

Step 3 if sum is even, stop
if not, go to step two.

They were then asked to fill in the blanks, changing one of the numbers in steps one or two from Dave's program so that Hank would start singing again. All of the fifth and sixth graders successfully completed this problem, changing three to an even number or four to an odd number. Half of the younger children could also do this extension question. Those who could not, either replicated the old program, producing an odd number, or did not complete the new one.

Children were then asked to change the number in step two so that Hank still would not sing "Row, Row, Row Your Boat." Again, none of the older children had any apparent difficulty with this problem. The responses from the third and fourth graders, however, were less often accurate and also difficult to interpret. In half of the cases, the children who gave correct answers were the same children who had answered the previous extension question incorrectly (only three third and fourth graders answered <u>both</u> questions correctly). This suggests that the number of third- and fourth-grade correct responses to these extension questions was inflated by the fact that they could guess <u>any</u> number and have a 50% chance of giving a correct response. This interpretation is consistent with the earlier finding that only two of the third and fourth graders demonstrated a full understanding of the idea that adding an even number to an odd produces an odd number.

On the final extension question, children were asked what would happen if Hank ran the following new program:

Step 1 Start with three

Step 2 Add four

Step 3 if sum is equal to
one million, stop

if not, go to step 2.

Six children were able to answer this question correctly. As one fifth grader explained, "He'll keep trying again. It won't add to one million. It'll never equal an even number." Most of the other children, however, were confused about this problem because they were not sure whether one million was an even number. For example, one sixth grader explained, "He will keep going 'till he...gets one million. It's hard to say if it will equal one million. You'd have to work it out...it's hard to say if one million is an even number."

Perceptions

When asked how Dave and Irving felt at the end of the story, all of the children described them in positive terms. Most reasoned that they felt good because they had succeeded in stopping the computer from singing. One sixth grader said they felt "happy, because they felt tired of listening to the computer singing, because they did the program 'till the computer would stop." Another said they felt "smart, because they accomplished something; they tricked the computer."

In this portion of the interview, the children were also asked if they had ever used a computer before, and if so, for what? All of them said they had used a computer before, most of them in school. Some of the programs mentioned were, "Logo," "Logo Golf," "States and Traits," and "Inside Story." Children said they used the computer in school for mathematics, spelling, and science.

Discussion and formative implications

All of the children recalled the problem that Dave and Irving were trying to solve. In terms of solution process, almost all of them remembered that Dave created a "program" to stop Hank from singing, although many described it as a "problem," or as "typing something into the computer." Recall of the solution to the problem, however, was not as high as usual. Only five children of the 24 were able to recall accurately the three steps of the program Dave created.

In response to the understanding questions, the majority of children questioned were able to define an even number. Older children also evinced an understanding of why the program loops -- the idea that an even number added to an odd always produces an odd number. In contrast, only two third and fourth graders could explain this idea; it is a concept that is usually not treated in school until the fifth grade. Because of this lack of understanding, they were less successful on the extension questions than the older children.

These findings suggest a few formative implications for a second season. In future segments on this topic, it might be beneficial to have one of the characters actually state the fact that an even number added to an odd always produces an odd.

Another issue is the relatively low recall of the three steps of the program. The program might have been more memorable if the graphics had been more salient -- if , for example, the "three" and "four" were numerals rather than words. How and why the program loops might also have been more understandable if the computer's calculations (3 + 4 = 7, 7 + 4 = 11 etc.) had been illustrated on the screen instead of just implied.

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"PHONEYMOONERS -- HOLE IN THE WALL"

Description of segment

Alph and Throckmorton must estimate how many bricks they need to repair a hole in the wall caused by Alph's bowling ball. They draw a diagram to figure out the area of this irregular shape.

Mathematical content

Mathematically, this is one of the more complex segments in **SQUARE ONE TV's** first season. The characters initially view the problem of determining the number of bricks needed as one of finding the area of an irregular region. They find an upper bound by placing the irregular shape inside a 19 X 7 "rectangle" (19 rows with 7 bricks per row). Using distributivity they calculate 19 X 7 as (20 - 1) X 7 = 140 - 7 = 133. Next they construct a list of the exact numbers of bricks in each of the 19 rows, group them judiciously to make the addition easier, and find the sum. Finally, they calculate the savings resulting from using the exact procedure instead of the estimate.

Relevant school experience

Area is introduced in second grade, although the only lessons involving non-standard units (which are generalized "square units") appear late in third grade and again in fourth. The texts include a few exercises involving areas of irregular regions, but estimation and bounds in connection with area occur only rarely. Associativity of addition appears initially in third grade, and commutativity starts in first grade; the kind of strategic grouping of single-digit addends illustrated in the sketch is not treated anywhere in the text series, however. Distributivity is introduced in the fifth grade, and is lightly treated there and in sixth grade.

Summary of responses

Recall

The only group that experienced any difficulties with the first three recall questions (problem statement, basic solution procedure, and solution) were the fourth graders, none of whom could remember that the characters made a drawing and counted bricks. The fourth "R" question, which asked for an explanation of how the characters used multiplication to figure out how many bricks were needed, proved much more troublesome. Not a single girl at any grade level gave an even partially correct response, and only four boys gave fully correct answers. The column addition seemed much more salient to most of the children, perhaps because it occurred later in the sketch and was more directly related to the final (exact) solution.

The next recall question asked why the characters thought that counting the bricks was a better idea (than using the estimate derived by multiplication). Surprisingly, no clear developmental trends appeared here -- for example the third-grade boys outperformed the sixth-grade boys. The difficulty seemed to be a confusion of the accuracy of the counting procedure (and the concomitant saving of money) with the speed of the estimate through multiplication. For example, one sixth grader said, counting the bricks was not that complicated -- easier and faster," which misses the point entirely, while a third-grade boy explained that by counting, "[you] get the right amount of bricks."

In the last recall question the children were given a copy of Throckmorton's drawing and column of numbers and were asked what he did to the list. Virtually all of the children remembered that he drew lines to group the numbers, and most realized that this was to make groups of 10.

Understanding

The first four of the "U" questions were designed to find out what the viewers understood about some of the computations that were performed. The first asked the children to interpret the equations, "20 X 7 = 140" and "140 - 7 = 133," which were presented to them on a card. No one could give a complete explanation of these, and the older children did not perform much better than the younger ones.

On the other hand, performance improved considerably when subsequent questions broke the process down into more manageable steps. These focused on (a) the meaning of 19 X 7; (b) the reason for doing 20 X 7 instead; and (c) the rationale for then computing 140 - 7, rather than 140 - 1. There are clear developmental trends here, with sixth graders doing substantially better than third graders, but two of the fourth graders and one fifth grader seemed to have an accurate understanding of the reasoning involved.

The three remaining "U" questions concerned the alternative method used in the sketch for determining the number of bricks. They focused on (a) the row-by-row connection between the bricks in the drawing and the numbers to be added; (b) the number of numbers to be added (i.e. 19 numbers -- one for each row of bricks); and (c) the rationale for grouping by tens (rather than by nines, for example). Although almost everyone realized that the column of figures referred to the bricks -- "for how many bricks there were," in the words of one third grader -- only the fourth, fifth, and sixth graders realized that each number referred to a specific row of bricks.

The next question, on the number of numbers that were added, was intended as an additional probe into children's understanding of the relationship between the geometry and the arithmetic of the situation. It was answered correctly by no one, even children who apparently realized that there were 19 rows of bricks. A few children tried to reconstruct the number of addends by recalling the specific groupings that Throckmorton performed on them, but the more direct route proved elusive to everyone. Finally, practically everyone, except for the fourth graders, understood the reason for grouping into subsets of ten. As one third-grade girl said, "They are equal to 10; 7 plus 3 is 10; 4 plus 6 is 10; 5 plus 5 is 10. Tens are easier to count: 10, 20, 30, ... instead of 9, 18, 27 ...."

Extension

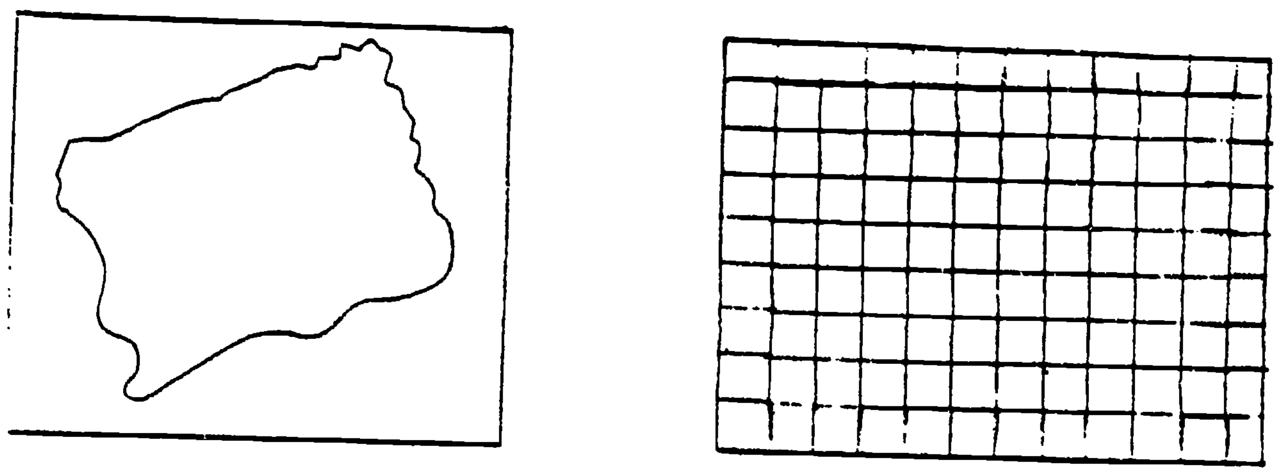
The four extension questions were aimed at three of the principal mathematical ideas embodied in the sketch. One question concerned the irrelevance of order when adding a column of numbers: five index cards, each bearing a number, were displayed in a column, and the sum (much too large to calculate quickly) was shown on a sixth card; another set of five cards with the same numbers were then shown in a different order, and the question was, "If we add these numbers up, will the total be bigger or smaller than the other one? How do you know?" Even third graders did fairly well on this question, with half of them giving fully correct responses. Virtually all of the older children had no difficulties with it at all.

Similarly, almost no one had any difficulty with the next "E" question, which involved grouping numbers in a column to make partial sums of 10 as the characters did in the sketch. The question that required the children to extend the Phoneymooners' mental arithmetic to calculate 98 X 7 was much more difficult. The desired response was to compute 100 X 7 and then adjust by subtracting two 7's, or 14, for a total of 686. One third of the fifth and sixth graders could apply the distributive principle successfully to this new problem; a few additional children used the standard algorithm, using their fingers to "write" on the table. Amazingly, one fourth-grade girl simply said, with no further explanation, "Times it in your head: 98 times 7 is 686."

A final extension question was designed to explore how a rectangular grid could be used to measure the area of an irregular shape. Each child was given a copy of the shape shown below (see Figure 13) and a sheet of transparent plastic marked off in one-inch squares.

Figure 13

Irregular Shape (a) and Rectangular Grid (b) Used in Interview



(a) (b)

The task was to find upper and lower bounds for the area inside the shape. The fact that both the shape and the grid were drawn on rectangular sheets of the same size apparently prevented everyone from rotating the grid so that the boundary of the shape roughly coincided with the directions of the grid lines. Hence, everyone was reduced to counting squares, more or less successfully.

Perceptions

All of the children had positive perceptions of Throckmorton. Some comments focused on how Throckmorton demonstrated competence and his subsequent gain of respect. For example, one fifth grader said, "On the real 'Honeymooners,' Ralph is always slapping Norton around and telling him what to do. So if he would have solved this problem, he would think that Alf would respect him more."

In explaining how they knew that Throckmorton felt happy, most of the children mentioned different physical cues, such as his facial expressions, or his "jumping around." For example, one third grader said that Throckmorton felt "wonderful" because, "he was hitting his buddy, pushing him and saying hooray!"

Similarly, most children perceived that Alph was pleased because the problem had been solved and, as a few children noted, it was solved before Alph's wife came home. Some children, however, described Alph in negative terms such as "stupid" or "jealous."

All but one of the children recognized that there was mathematics presented in the segment. Most children, especially the younger ones, referred generally to addition, multiplication, and subtraction. A few fifth graders, however, spoke more specifically in terms of the numbers involved and, in the case of one child, the concepts of width and length. This child said there was a lot of mathematics in the piece; "20 x 7, 140 - 7, width and length...long columns. A lot! Too much for me."

Discussion and formative implications

Clearly, this is a complex sketch that illustrates a variety of interconnected mathematical approaches to a non-standard problem. While virtually everyone grasped the basic problem and its solution, none of the children interviewed had a complete understanding of all its facets. Even though many appeared to understand substantial parts of the segment, it was only when they were presented sequentially and in isolation. Responses to extension questions were mixed as wall, ranging from almost unanimously correct answers, for one involving addition of numbers in different orders, to relatively poor performance on a question about the area of an irregular shape. In interpreting children's responses, however, one must remember that the "Hole in the Wall" problem is far more complex then the word problems ordinarily presented in textbooks.

One point that could be clarified is the explicit connection between the drawing of the bricks and the column of numbers. Another is the relationship between the hole in the wall and the 19 X 7 "rectangle" that forms an upper bound of the area. A third point -- but one that has been perennially troublesome -- is the distributive principle and its applications to mental arithmetic.

Children's apparent difficulties with the segment as a whole lead to a more general concern about the sheer amount of material that can be effectively presented in a single sketch. Even if the points of confusion listed above were dealt with somehow, the number of disparate mathematical ideas that can be compressed into a relatively short segment remains a matter for empirical investigation. One of the overarching aims of **SQUARE ONE TV** is to illustrate the interconnections among various parts of mathematics, but care must be taken not to bite off more than the target audience can chew. "Phoneymooners -- Hole in the Wall" may exceed the maximum mouthful.

"DADDY KNOWS DIFFERENT -- STAINLESS FORKS"

Description of segment

Rusty gives his father the option of paying him a fixed allowance or starting with a penny and then doubling the previous day's amount for a month. Surprisingly, the amount on the 30th day would be well over $5 million, far more than the initial amount suggested.

Mathematical content

The children's responses to this segment must be interpreted in light of its two overarching mathematical subtleties. The first is the unusually large numbers involved (and it should be noted that reporting the month's total in dollars, when starting with one cent, underreports by a factor of 100; the total is really $2^{30} - 1$, not $(2^{30} - 1)/100$. The second subtlety is the astonishing rapidity with which the relatively small amounts of money at the beginning of the month become so large so quickly. Exponential growth is indeed an awesome phenomenon, one with which many adults are not completely comfortable.

Relevant school experience

The simple doubling that forms the basis of this sketch occurs before third grade in the Addison-Wesley text series. Dollar and cents place value notation appears in the second grade. Whole numbers through hundred millions occur in fourth grade. Exponentation is not introduced until the sixth grade, however. Exponential functions and, in particular, exponential growth are not part of the K-6 curriculum.

Summary of responses

Recall

The 12 items in the protocol for "Daddy Knows Different" were divided evenly among the three levels (R, U, E). As usual, the first three items were intended to determine what the problem was, what was done to solve it, and what the solution was. Virtually all of the children, except for the third graders, were completely correct in their recall of the problem statement and solution. To be coded as "Y" (fully correct) the answer to the second question (on the solution process) was required to include mention of all the relevant pieces: making a list, starting with a penny and doubling each day for 30 days. Any response that did not include all of these was coded as "M+" or lower. Using this stringent criterion only 5 of the 24 responses qualified as "Y."

In the fourth "R" question the children were shown a copy of the table that Rusty used in the sketch and asked, "What is this a list of?" Everyone except two fourth-grade boys gave fully correct answers to this.

Six weeks later, 12 children were asked to recall what happened in this segment. The most typical response mentioned the fact that they were dropping dishes. Five children also mentioned the issue was Rusty's allowance, and three remembered that there was "doubling" involved in Rusty's plan. For example, one sixth grader explained that "...the son said, 'pay me a penny-a-day, double every day.'" A few children also recalled that this amounted to a lot of money, although no one remembered the exact amount (guesses included $15, $1300, $1,000,000 and $10,000,000). As another sixth grader said, "Ricky had to do the chores and his father should pay him. Comes out to a lot of money...one cent, two cents, three cents, comes out to a million."

Understanding

The four "U" questions, as a group, were intended to probe how well the children understand and appreciate how the payment plan grows over the month. To this end each child was provided with a copy of Rusty's list which was modified to include a column of day numbers on the left side of the page. (The purpose of this was to make the exponential function more explicit.) Using this prop, the first three "U" questions were: "How much money would Rusty make on the fifth day?," "How much money would he make total for the first four days?," and "How much money would he make total at the end of a week?" The only difficulty that most of the respondents had here was in distinguishing between the amount received on a particular day and the total amount received up to and including that day. Only the sixth graders could compute the week's total of $1.27 correctly; most of the others simply believed that the seventh day's amount (64 cents) was the answer.

The final "U" question was designed to contrast the relatively small payments during the first week with the enormous amounts of money earned over the full month. The interviewer placed a dollar bill, a quarter and two pennies on the table and said, "Rusty would make this much money at the end of one week -- $1.27. So how could he make $10,737,418.23 at the end of 30 days?" An interesting pattern of responses emerged here, ranging from misunderstanding of the essential features of the contrast, through outright rejection of the interviewer's claim, to final acceptance of the realities of exponential growth. Some examples:

> A third-grade girl: The other week it adds up to \$1.28. Each week he gets that amount, and it adds up.
>
> A fifth-grade boy who earlier insisted that the time period covered by the sketch must be 18 months, not one month: seven times four is 28 -- seven days in a week, 4 weeks in a month. That's only around \$38. He keeps going for 18 months. There's no way! [He] can't double it up in 30 days!
>
> A sixth-grade girl: It increases. It's one more cent than what's there. Double the \$1.28. Add on Sunday; and one cent more. Double \$1.28 to \$2.56, then on and on: double \$2.56....

Extension

The four "E" questions pursued the exponential function beyond the boundaries of the sketch. The first pitted Rusty's plan against one that paid 50 cents a day, and virtually everyone agreed that the latter plan was better for the first week. The last three items introduced a new (linear) payment plan in which the first day's payment was \$1,000 and each subsequent day \$1,000 more than the preceding day's. Each child was given a new chart, with day numbers in the leftmost column, the figures from Rusty's plan (for all thirty days and a total at the bottom) in the center, and the "new plan" (with only the first four days' amounts, \$1,000 through \$4,000 filled in) on the right. After two questions designed to be sure that the children understood what the new plan involved, the final extension question was, "Which total will be bigger at the end of the month, the one in Rusty's plan or the new plan?" The only children who were confident that Rusty's plan was more advantageous were the fifth-grade boys (including the one quoted above) and one sixth-grade boy. Many of the other children focused only on the beginning of the month; one third-grade girl, for example, said, "The new plan. You get 100 every day, . . 200, 300, 400. With Rusty's plan you only get one cent, two cents, three cents, four cents."

Perceptions

All of the children described Rusty in positive terms, mentioning his pride, intelligence, and happiness. When probed, most of the children referred to the increase in Rusty's allowance as an explanation for why he would feel good. One sixth grader said, "He was enjoying himself cause he was getting money. I'd be laughing with joy."

Most of the children also had positive perceptions of Rusty's father, usually describing him as "happy" or "glad." A number of children, on the other hand, described Rusty's father as feeling "sad," "annoyed," or "angry." The most common explanation for this was that the father would now have to work extra jobs to pay his son's allowance. For example, a sixth grader said that the father fainted because, "He couldn't make that much working double or triple jobs. Ten million - that's a lot of money - he couldn't even make that much in a year!"

Everyone said mathematics was used in the segment, and most children referred specifically to addition or multiplication. Some children mentioned numbers involved. For example, one child stated, "You have to add. One day he gets one cent and then another day he gets two cents...add it up and then you get the answer and that's math."

Discussion and formative implications

This sketch and the research protocol built upon it take familiar and accessible concepts -- a day, a week, a month, a penny, the doubling function -- and create, in short order, numbers that are beyond the intuitive grasp of most children in the target age range. Not surprisingly, students' success with the ideas presented is mixed. Children recalled the statement and solution of the problem and apparently understood the mechanics of the payment plan. In contrast, the meaning of the huge numbers and the process through which they are generated are elusive for many, particularly the younger children. In any case, the segment provoked spirited discussion among some of the older students.

Two improvements are immediately apparent: first, the exponential function involved would surely have been clearer if the day numbers had been written on Rusty's table. Second, a third column listing each day's cumulative earnings might have clarified the relationship between "earned today" and "earned to-date."

V. CONCLUSIONS

In drawing conclusions from the study it is helpful to keep in mind some background information:

- We have a reasonably good idea of the subjects' mathematical background, as presented in formal school settings, under the reasonable assumption that the content of classrooom instruction follows closely the content of the texts. (This information is summarized for each segment in the preceding sections.) Generally speaking, there is not much overlap between the content of the **SQUARE ONE TV** sketches and the content of the texts -- and this is by design, not happenstance.
- Similarly, we have a fairly good idea of what concepts, methods, facts, etc., are easy or difficult for the larger population of children in the target age group. In part, this information comes from large-scale studies such as the ones periodically conducted by the National Assessment of Educational Progress (Carpenter, Corbitt, Kepner, Lindquist & Reys, 1981) and in part this comes from a very large number of individual studies of particular mathematical topics. (See, for example, Suydam (1986) for a bibliography of the most recent literature in the field.) The conclusions to be drawn from this literature are that third through sixth graders in the U.S. are adept at simple computation and can cope successfully with one-step routine word problems, but that their performance falls off precipitously in non-routine problems that require more than a single straightforward step or that involve measurement.

o Looking at the project from a different direction, we know what leading reports on the status of mathematical education have asserted are the greatest needs in the area -- what is still important and what is not. (See, for example, Board of Mathematical Sciences, 1983; Hill, 1987; Romberg, 1984.) This literature is unanimous in stressing the centrality of problem solving in mathematics and in urging far less emphasis on the mechanical paper-and-pencil computational algorithms that typically loom so large in the elementary school child's mathematical experience.

o In addition, we must keep in mind **SQUARE ONE TV**'s goals as a source of <u>informal</u> mathematics education -- goals that were summarized at the very beginning of this report.

With these points in mind, what conclusions can be drawn from this study? Several seem evident.

Looking at the 10 segments tested, it is apparent that **SQUARE ONE TV** is generally successful in making its presentations <u>accessible</u> to viewers across the age range. At the lowest level, even the youngest children were able to recall important storyline and mathematically relevant information. Across all grades, the performance pattern on recall questions is very strong; the numbers, in fact, could not be much higher. Approximately 80% of the youngest viewers' responses to recall questions were either partially or fully correct, and performance increased across grade levels. At the highest grade level, about 90% of the responses were satisfactory.

Recall of problem solving, in particular, was very high for all children. Children could identify the problems, describe the processes used to approach and solve the problems, and recall the solutions. The material is presented in such a way that children can extract important Goal II information; children can remember the information that is fundamental to an understanding of the problem-solving presentation.

The accessibility of these 10 segments is particularly significant when one considers the point made earlier, that there is not much overlap between the content of classroom instruction and the content of **SQUARE ONE TV**. Indeed, one of the main challenges of the series is to present unfamiliar mathematics in a way that has meaning to children across the age range. The high level of recall suggests that the segments pose problems that give children an entry point into the unfamiliar mathematics, making the material accessible to even the youngest viewer.

Responses to understanding questions yield a related conclusion. It appears that **SQUARE ONE TV** was successful in gearing these 10 segments to a span of ages, i.e., that these 10 segments are generally age-appropriate. The data on the understanding questions form a consistent pattern: the level of performance on understanding questions increases with grade level, from 65% in grade three to about 80% in grade six. Hence one can conclude that the presentations are easy enough that young children can understand them, but not so easy that younger children can grasp them as well as older children. The segments instead function like "one room school houses," where children at different levels have different levels of understanding, and yet most have meaningful experiences with the mathematics presented.

Another issue connected to the question of age-appropriateness is the overall level of the children's comprehension of the 10 segments. Here, the research reveals that even the youngest children (third and fourth graders) are answering about two thirds of the understanding questions correctly. One must remember that some of these questions were designed to test for specific mathematical knowledge that, while not presented in the segments, enhances understanding. In some cases, the youngest children missed these questions simply because the information was completly new to them. This partially explains why the level of performance on the understanding questions is lower than on the recall questions.

More importantly, the overall results must be interpreted in light of the fact that the target audience as a whole performs less well on non-routine problems involving more than one step, and on problems dealing with measurement. Two of the segments tested in this study dealt with measurement, and all presented non-routine problem solving. Considering this, it is striking that even the youngest children comprehended a substantial amount of the material presented.

In a few segments, of course, the presentation of unfamiliar mathematics could have been clearer. Needless to say, the challenge of explaining some of these concepts in such a short period of time is indeed formidable. Nonetheless, opportunities were lost, therefore the formative implication sections of this report identify places were there is room for improvement in Season II.

Another more global issue is the "extendability" of these 10 problem-solving presentations. Clearly, results from this study show that some children from all grades can extend the mathmematics presented in the segments. On extension questions, at least 50% of the third graders' responses and 80% of the sixth graders' responses were acceptable. As with the understanding questions, the variance in the performances of the youngest and oldest children can be interpreted as an indicator of age-appropriateness. While the sixth graders performed significantly better than the third graders on these questions, both groups were challenged. Again this level of success on extension questions must be interpreted in light of the past findings outlined earlier: children in this age-range generally have difficulty with mathematical problems that go beyond straightforward computation.

The detailed segment-by-segment analyses support these overall extension findings. They also reveal information about the <u>processes</u> children used to solve the problems presented to them. When tackling extension questions, a number of children imitated the problem-solving heuristics modeled by the character in a given segment. In the case of "I Love Lupy -- Licorice," for example, younger children solved problems similiar to Lupy's using her method of aligning the 5-inch and 7-inch strands of licorice next to the 24-inch strand. From these findings one can draw the conclusion that, in general, these segments succeed in modeling problem-solving heuristics.

In looking at the responses to extension questions, it is also evident that other children employed alternative processes in solving a given extension problem. In fact, in some cases the variety of approaches attempted in solving extension questions was indeed impressive. For example, in "Bobo's Dilemma," children from all grades made numerous, exhaustive attempts to solve the problem presented, using very different processes that often incorporated outside elements (the other clowns, weights etc.). In "I Love Lupy -- Licorice," younger children used hands-on materials to assist them in solving a new problem, while older ones used addition or multiplication in solving the prcblem abstractly.

Ultimately, children's performances on the extension questions show that the material has sufficient content to allow for worthwhile extension; the variety of approaches used in tackling these questions suggests that the segments can stimulate diverse problem-solving activity. This has important implications for the potential use of SQUARE ONE TV in the schools. Based on these 10 segments, it seems that SQUARE ONE TV can function as a springboard to future learning, for if a child can extend after viewing in the interview, he or she can also extend in the classroom.

Another conclusion that can be drawn from the research relates to children's perceptions of the problem solvers in the segments. In almost all cases, children had positive perceptions of these characters; they usually described them as "happy," "glad," or "proud." In many cases, they also related these feelings back to the fact that they had solved the problem at hand, or to the fact that, in doing so, the characters had demonstrated competence and gained respect. Ultimately, these findings suggest that the characters could potentially serve as positive role models for problem solving. In Season II, research will examine children's attitudes towards the characters who solve mathematical problems, an issue fundamental to Goal I of the series.

One final important question for **SQUARE ONE TV** is whether these segments succeed in providing a motivating context for learning about mathematics. In general, the answer to this question appears to be yes. Perhaps the most salient example of this is "But Who's Multiplying?" Children of all ages played this game with enthusiasm and competence. The segment provided a motivating context for an area of mathematics (multiplication "facts") that is usually the subject of endless drill and practice starting in second grade and, more importantly, for the strategic thinking needed to play the game effectively. Another example is "Daddy Knows Different -- Stainless Forks," which presented the unfamiliar concept of exponential growth and elicited spirited discussions on the subject among some of the older children. One also thinks of "Bobo's Dilemma," a segment that was particularly successful in this regard. Here, children tackled extension questions with enthusiasm and persistence, and, in a few cases, continued to try and solve the problems presented until told to stop. The problem set forth was clearly one that interested and motivated them.

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APPENDIX A
Statement of Goals

SQUARE ONE TELEVISION--ELABORATION Of GOALS

GOAL I. To promote positive attitudes toward, and enthusiasm for, mathematics by showing:

A. Mathematics is a powerful and widely applicable tool useful to solve problems, to illustrate concepts, and to increase efficiency.

B. Mathematics is beautiful and aesthetically pleasing.

C. Mathematics can be understood, used, and even invented, by non-specialists.

GOAL II. To encourage the use and application of problem-solving processes by modeling:

A. Problem Formulation

1. Recognize and state a problem.
2. Assess the value of solving a problem.
3. Assess the possibility of solving a problem.

B. Problem Treatment

1. Recall information.
2. Estimate or approximate.
3. Measure, gather data or check resources.
4. Calculate or manipulate (mentally or physically).
5. Consider probabilities.
6. Use trial-and-error or guess-and-check.

C. Problem-Solving Heuristics

1. Represent problem: scale model, drawing, map; picture; diagram, gadget; table, chart; graph; use object, act out.
2. Transform problem: reword, clarify; simplify; find subgoals, subproblems, work backwards.
3. Look for: patterns; missing information; distinctions in kind of information (pertinent or extraneous).
4. Reapproach problem: change point of view, reevaluate assumptions; generate new hypotheses.

D. Problem Follow-up

1. Discuss reasonableness of results and precision of results.

2. Look for alternative solutions.

3. Look for alternative ways to solve.

4. Look for, or extend to, related problems.

GOAL III. To present sound mathematical content in an interesting, accessible, and meaningful manner by exploring:

A. Numbers and Counting

1. Whole numbers.

2. Numeration: role and meaning of digits in whole numbers (place value); Roman numerals; palindromes; other bases.

3. Rational numbers: interpretations of fractions as numbers, ratios, parts of a whole or of a set.

4. Decimal notation: role and meaning of digits in decimal numeration.

5. Percents: uses; link to decimals and fractions.

6. Negative numbers: uses; relation to subtraction.

B. Arithmetic of Rational Numbers

1. Basic operations: addition, subtraction, division, multiplication, exponentiation; when and how to use operations.

2. Structure: primes, factors, and multiples.

3. Number theory: modular arithmetic (including parity); Diophantine equations; Fibonacci sequence; Pascal's triangle.

4. Approximation: rounding; bounds; approximate calculation; interpolation and extrapolation; estimation.

5. Ratios: use of ratios, rates, and proportions; relation to division; golden section.

C. Measurement

1. Units: systems (English, metric, non-standard); importance of standard units.

2. Spatial: length, area, volume, perimeter, and surface area.

3. Approximate nature: exact versus approximate, i.e., counting versus measuring; calculation with approximations; margin of error; propagation of error; estimation.

4. Additivity.

D. Numerical Functions and Relations

1. Relations: order, inequalities, subset relations, additivity, infinite sets.

2. Functions: linear, quadratic, exponential; rules, patterns.

3. Equations: solution techniques (e.g., manipulation, guess-and-test); missing addend and factor; relation to construction of numbers.

4. Formulas: interpretation and evaluation; algebra as generalized arithmetic.

E. Combinatorics and Counting Techniques

1. Multiplication principle and decomposition.

2. Pigeonhole principle.

3. Systematic enumeration of cases.

F. Statistics and Probability

1. Basic quantification: counting; representation by rational numbers.

2. Derived measures: average, median, range.

3. Concepts: independence, correlation; "Law of Averages."

4. Prediction: relation to probability.

5. Data processing: collection and analysis.

6. Data presentation: graphs, charts, tables; construction and interpretation.

G. Geometry

1. Dimensionality: one, two, three, and four dimensions.

2. Rigid transformations: transformations in two and three dimensions; rotations, reflections, and translations; symmetry.

3. Tessellations: covering the plane and bounded regions; kaleidoscopes; role of symmetry; other surfaces.

4. Maps and models in scale: application of ratios.

5. Perspective: rudiments of drawing in perspective; representation of three-dimensional objects in two dimensions.

6. Geometrical objects: recognition; relations among; constructions; patterns.

7. Topological mappings and properties: invariants.

APPENDIX B
Segment Descriptions

	TIME
BOBO'S DILEMMA	3:56

Bobo the clown must get from an outer circus ring to the center platform. He is given two boards to help him; however, each board is 6 1/2 feet long, and the center platform is 7 feet from the outer ring. Neither Bobo nor the boards can touch the ground. After several attempts, Bobo finds a solution: he places one board so that just its ends are on the ring, and he places the second board pendicularly from the midpoint of the first board to the center platform.

I LOVE LUPY -- LICORICE	9:00

Lupy is newly hired by a candy manufacturer to cut 5-inch and 7-inch sticks of licorice from strands that come from the factory in 2-foot lengths. The aim is to do it in such a way that no licorice is left over. She tries a number of ways (e.g., cutting a single 5-inch piece or three 5's and a 7) all of which leave some unused licorice. Finally, she realizes that two 5-inch sticks and two 7-inch sticks can be obtained from a 2-foot strand with no waste.

DUELISTS	5:54

Using a grid of the area, two knights try to figure out all of the possible meeting points halfway between their castles in order to avoid having to go out and fight a duel.

IN SEARCH OF THE GIANT SQUID	3:51

The navigator of a submarine fails to consider the concept of scale, and mistakenly thinks that an iceberg is centimeters, instead of kilometers, away.

PHOTOGRAPH ALL ABOUT IT	4:20

The Prdictors must predict who will be elected governor. In doing so, they determine all the possible orders for finishing if there are two, three, or four candidates. They use photographs to illustrate how the number of possible outcomes can be determined.

CALLOUS -- THE SURVEY	9:00

J.B. Callous and his family conduct a survey to find out why Callous Candy Gumdrop sales are so low in their hometown of Grasshopper Gulch.

BUT WHO'S MULTIPLYING 4:35

Two child contestants attempt to cover three numbers in a row (either vertically, horizontally, or diagonally) on the Product Board by selecting factors of these numbers from the Factor Board and calling out the resulting product. The first player to cover three in a row wins the game.

KUBRICK'S RUBE 2:57

In this parody of the film 2001: A Space Odyssey, astronauts Irving and Dave devise a looping program to get Hank the computer to stop singing "Row, Row, Row Your Boat."

PHONEYMOONERS -- HOLE IN THE WALL 7:00

Alph and Throckmorton must estimate how many bricks they need to repair a hole in the wall caused by Alph's bowling ball. They draw a diagram to figure out the area of this irregular shape.

DADDY KNOWS DIFFERENT -- STAINLESS FORKS 5:06

Rusty gives his father the option of paying him a fixed allowance or starting with a penny and then doubling the previous day's amount for a month. Surprisingly, the amount on the 30th day would be well over $5 million, far more than the initial amount suggested.

APPENDIX C
Analysis of Ten Test Segments

Segment	Repeated Parody	Goal II	Goal III	Cast
"Bobo's Dilemma"	No	A1 A2 A3 C1e C3c C4a	G6 C2	Arthur, Cris, Luisa
"I Love Lupy -- Licorice"	Yes	A1 A2 B3 B4 B6 D1 C1e C4a	C2 B1 B2	Cynthia, Reg
"Duelists"	No	A1 B4 D2 C1e C3a	G4 C1	Beverly, Larry, Cris
"In Search of the Giant Squid"	No	A1 B3 B4 D1 D4 C1a	C1 G4	Arthur, Beverly, Cris, Reg
"Photograph All About It"	No	A1 A2 B4 C1e C2a C3a	E1 B1	Larry, Luisa
"Callous -- The Survey"	Yes	A1 A2 A3 B1 B2 B3 B4 D1 C1c C1d C4a	F5 F6 A5 F4	Cris, Larry, Arthur, Luisa, Beverly
"But Who's Multiplying"	Yes	A1 B4 B6 C1b C1c C2c	B1 B2 D1 F4	Larry, Kids
"Kubrick's Rube"	No	A1 A2 A3	D1 D2	Arthur, Cris
"Phoneymooners -- Hole in the Wall"	Yes	A1 A2 A3 B4 D1 C1b C4a	C2 B1 C1 G4	Cynthia, Cris, Larry
"Daddy Knows Different-- Stainless Forks"	Yes	A1 A2 B4 D1 D4 C1c C4a	A1 B1 D2	Larry, Cris

APPENDIX D
Permission Slip

CITY SCHOOL DISTRICT, CITY OF NEWBURGH
NEW WINDSOR SCHOOL
175 QUASSAICK AVENUE
NEWBURGH, NEW YORK 12550

OFFICE OF THE PRINCIPAL

February 18, 1987

Dear Parents:

Your child has been selected to take part in an exciting program organized by the Children's Television Workshop, the makers of Sesame Street, 3,2, 1 Contact, Electric Company and Square One T.V.

The children will be exposed to new television programs and will be asked to comment on them after viewing taped segments. The students will be taken out of class only twice, for one hour each time, during the ten week period. The entire program should be a learning process for all involved. For the student's participation, they will receive a small gift of thanks from CTW.

Please sign the permission slip below and return it to your child's teacher by Thursday, February 19, 1987.

Should there be any questions, please do not hesitate to call me at 561-1866.

Sincerely,

Steven Runberg

Steven Runberg
PRINCIPAL

SR:cn

- -

Student Name ____________________

Teacher ____________________

Grade ____________________

__________ Yes, I would like my child to participate in this program.

__________ No, I do not want my child to participate in this program.

APPENDIX E
Viewing Questionnaire

Date____________________

Grade____________________

Name____________________ Teacher________________________

Girl_____ Boy_____

Please wait for instructions. Your teacher will read each question with you.

1. Have you ever watched SQUARE ONE TV at home before they came to our school?

   Yes_____ No_____

2. Please check the answer that best describes how many times you have watched the show:

   Never __________

   1 or 2 times __________

   Around 5 times __________

   10 times or more __________

3. Have you ever watched SQUARE ONE TV at home since they came to our school?

   Yes_____ How many times?_____. No_____

APPENDIX F
Instructions for Interviewers

PROBLEM SOLVING/COMPREHENSION STUDY

General Directions to Tester

Before viewing, say:

Please sit down and I'll explain what we're going to do today, OK? This is (Alex) and I'm (Tina). We're going to show you a segment from SQUARE ONE TV, the TV show you saw yesterday. We're going to ask you some questions about what you saw, OK? Good, let's watch!

After viewing, say:

We're going to ask you some questions now. As we talk, we're going to keep the video camera and take notes so that we don't forget what you say and then later after we get back to the office we'll be able to look at our conversation again OK? Good! Let's write down you names.

(Proceed with protocol)

For two-part segments, (e.g., I Love Lupy), there will be 5 seconds of black between parts. During the black, say: that was the first part. Keep watching, because here comes the second part!

APPENDIX G
Example of Protocol

COMPREHENSION/PROBLEM SOLVING STUDY
Daddy Know Different - Forks

Tester ________
Date ________
Grade ________
Site ________

A. Child Name ________	B. Child Name ________	C. Child Name ________
Sex ______	Sex ______	Sex ______
Eth ______	Eth ______	Eth ______
Age ______	Age ______	Age ______

I'd like to ask you some questions, OK? Raise your hand when you want to talk, OK? Good!

	Responses		
	Child A	B	C
1. What happened in the story you saw last time?			
2. In the story you saw today, what was the problem Rusty and his dad were trying to solve?			

Answer: . How much money Rusty should be paid.

	Responses	
	Child A	B

3. How did Rusty and his dad figure out how much money Rusty would get? What did they <u>do</u> to figure out how much money Rusty would get?

   Answer: . They used a list

   . They started with a penny and doubled it every day for 30 days to find the total.

4. What was the solution to Rusty and his dad's problem?

   <u>Probe</u>: About how much money would Rusty make if his dad paid him all the money?

   Answer: . They figured out that Rusty's dad would have to pay him over 10 million dollars.

5. <u>Hold list of numbers from story and say</u>: We saw this list of numbers in the story on TV. What is this a list of?

   Answer: . How much money Rusty would get each day for 30 days.

6. <u>Give each child his or her own list</u>. Using this list, how much money would Rusty make on the fifth day?

   Answer: . 16 cents

Responses

Child A B C

7. How much money would he make total for the first 4 days?

Answer: . 15 cents

8. How much money would he make total at the end of a week?

Answer: . $1.27

9. Put one dollar, one quarter, and two pennies on the table. Rusty would make this much money at the end of one week, $1.27. So, how could he make $10,737,418.23 at the end of 30 days?

Answer: . It keeps doubling over and over and you add them up.

10. TAKE PROP AWAY
Let's say that you were going to get an allowance at home for one week, OK? Let's also pretend that you have a choice, you can either get 50 cents a day for one week; Or, you can use Rusty's plan for one week. You know a penny the first day, double that the second day, and so on for one week. Which way would you want to get paid? Give each child pad and pencil.

Answer: . 50 cents a day. That plan totals $3.50. Rusty's plan totals $1.27.

	Responses		
	Child A	B	C

11. Give each child a handout. Point to appropriate columns and say: On the left side of this chart, you see what day it is. In the middle, you see Rusty's plan. On the right, over here, is a new plan. See, on the new plan, you'd get paid $1,000 the first day, $2,000 the second day, $3,000 the third day, and so on. How much would you get paid on the fourteenth day? Put your answer in the box. When all done, ask: How do you know?

    Answer: . $14,000; Each day is $1,000 more than the previous day. If first day is $1,000 then 14th day is $14,000.

12. Look at your paper again. What would your total be at the end of the fourth day?

    Answer: . $10,000

13. Which total will be bigger at the end of the month, the one in Rusty's plan or the new plan?

    Answer: . Rusty's plan.

	Responses		
	Child A	B	C

14. I just want to ask you a couple more quick questions before you go, ok? How do you think Rusty felt when they solved the problem.

    Answer: . Note responses.

15. How do you think the dad felt when they solved the problem?

    Probe: How do you know?

    Answer: . Note responses.

16. Was there any mathematics in the TV story today?

    Answer: . Note responses.

Table I-1

Frequency of Responses to Viewing Questionnaire
at Beginning and End of Study

	Never	1-5 Times	Over 10 Times
Beginning of Study	41%	44%	15%
End of Study	16%	37%	47%

N = 95

<u>Note</u>: This Table includes only those children who were tested twice (Time 1 and Time 2) <u>and</u> completed the Viewing Questionnaire at the beginning and end of the study. Two caveats should be remembered in reading this table: self-report viewing estimates are not typically very accurate, and viewing estimates may be inflated due to the presence of SQUARE ONE TV researchers at the site.

APPENDIX I
Viewing Questionnaire Results

Figure G-1

Percentages of "Y" (Fully Correct) and "M" (Mid-Level) Responses on Recall Questions, by Segment

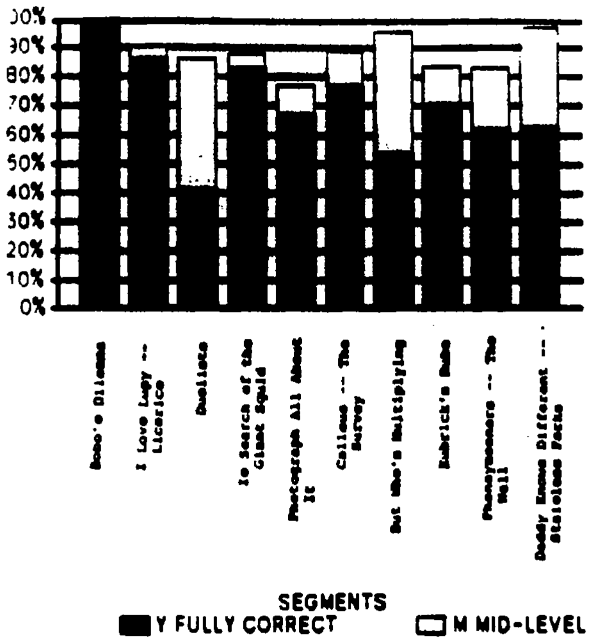

Figure G-2

Percentages of "Y" (Fully Correct) and "M" (Mid-Level) Responses on Understanding Questions, by Segment

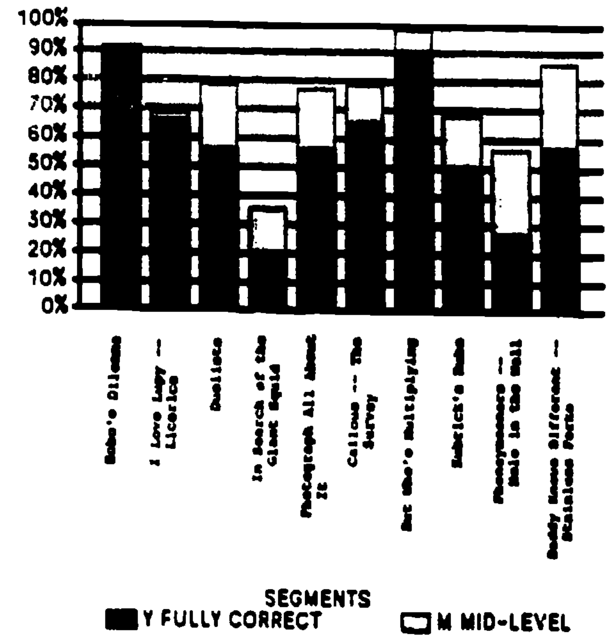

Figure G-3

Percentages of "Y" (Fully Correct) and "M" (Mid-Level) Responses on Extension Questions, by Segment