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ABSTRACT

The purpose of this exploratory, descriptive study was to examine how children process different tasks of comprehension presented in graphical form. During the Spring 1981, 8 fourth graders and 9 seventh graders were interviewed. The children were presented with graphs accompanied by six questions reflecting three levels of comprehension: "reading the data," "reading between the data," and "reading beyond the data." The children approached the tasks of comprehension by employing text-/schema-based processing strategies, text-based processing strategies, and schema-based processing strategies. These three types of strategies led to both correct and incorrect responses. Most students were aware of the need for, and also used, a text-based strategy for "reading the data" directly from the graph. Most seventh-grade and higher achieving fourth-grade students demonstrated the text/schema integration strategy successfully on problems. Seventh graders seemed to know when to rely on schema-based strategies, even when not required by the example, whereas fourth graders failed to note, process, and/or adjust for inconsistent information on a bar graph designed with numbers decreasing from bottom to top on the vertical axis. (Author/MP)

Processing Information in Graphical Form[1]

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Abstract

The purpose of this exploratory, descriptive study was to examine how children process different tasks of comprehension presented in graphical form. During the Spring 1981, 8 fourth graders and 9 seventh graders were interviewed. The children were presented with graphs accompanied by six questions reflecting three levels of comprehension: "reading the data," "reading between the data," and "reading beyond the data."

The children approached the tasks of comprehension by employing text-/schema-based processing strategies, text-based processing strategies, and schema-based processing strategies. These three types of strategies led to both correct and incorrect responses. Most students were aware of the need for, and also used, a text-based strategy for "reading the data" directly from the graph. Most seventh-grade and higher achieving fourth-grade students demonstrated the text/schema integration strategy successfully on problems. Seventh graders seemed to know when to rely on schema-based strategies, even when not required by the example, whereas fourth graders were less successful. A number of fourth- and seventh-graders failed to note, process, and/or adjust for inconsistent information on a bar graph designed with numbers decreasing from bottom to top on the vertical axis.

This paper includes a description of how these results highlight the statistical results of a previous study, a description relating the findings to other current research, and suggestions for future research.

Processing Information in Graphical Form

Processing information in our highly-technological society is dependent upon readers' ability to comprehend graphs. Our future citizens may not be adequately prepared for this form of communication because the results of the Second National Assessment of Educational Progress (NAEP) indicate that children's ability to interpret and integrate the data in graphical form is limited (Bestgen, 1980; NAEP, 1979).

Generalizing, drawing inferences and predicting from data are high-level cognitive skills which are essential if the message of the graph is to be deciphered. Therefore, a research study (Curcio, Note 1) was conducted to attempt to identify factors independent of reading and mathematics achievement, that contributed to fourth- and seventh-graders' ability to comprehend mathematical relationships expressed in graphs. The statistical results suggested that readers' prior knowledge contributes to their ability to comprehend the message in a graph.

The three aspects of prior knowledge that were identified included prior knowledge of the topic of the graph (which is usually depicted by the title and axes' labels), prior knowledge of the mathematical content in the graph (i.e., the mathematical concepts and skills that are implicit in the pictorial display), and prior knowledge of the graphical form (i.e., bar graphs, circle graphs, line graphs, or pictographs). For both fourth- and seventh-graders, the most salient aspect of prior knowledge of the graph that contributed to graph comprehension was that of mathematical content. Younger children (e.g., fourth graders) seem to rely more heavily upon the explicit features of the graph (i.e., the topic and graphical form) for its meaning than older children (e.g., seventh graders). As the children's global knowledge base widens and they are becoming more adept at abstract thinking (i.e., by the time they reach seventh grade), there seems to be less concern for the topic and graphical form which drop out as significant variance factors (Curcio, Note 1).

This previous research study (Curcio, Note 1) focused on the "product" of each measure, i.e., the results of objective testing. The questions were designed to determine what prior knowledge (including knowledge of topics, mathematical content, and graphical form) about the specific graphs students had, and how well they were able to comprehend the mathematical relationships expressed in those graphs.

It was thought that additional information about how prior knowledge affects graph comprehension might be revealed by asking children to respond to graph items requiring them to "think aloud" as they solved each problem. Similar to other researchers (Clement, 1982; Janvier, 1978; Resnick & Ford, 1981), it was believed that designing such protocols would reveal the "process" of comprehension, highlighting some of the strategies that might be employed by children to determine the "meaning" of the graph, and thus, enhance the statistical results of the previous study.

The Sample

Eight fourth graders (3 girls and 5 boys) and 9 seventh graders (5 girls and 4 boys) who participated in the previous study were interviewed and their responses were taped. In the following text, children are referred to by an identification number of the form SGN, where S = student, G = either 4 or 7 (representing the grade level), and N = 1 through 9 (not representative of the order interviewed). The children were selected so that different levels of reading and mathematics achievement were represented. See Table 1 for a list of the students' reading and mathematics profiles.

Insert Table 1 about here

Procedure

The interviews were conducted by three individuals who were prepared to follow the interview protocol (Curcio, Note 1, p. 176). Two of the interviewers were totally unknown to the children. One interviewer had been at the school on previous occasions. Each interview lasted approximately 40 minutes. All interviews were completed in two days, during the Spring, 1981. The interviews took place in the school library and a resource center, where the conditions were quite similar. The child was put at ease by informal chatting about the child's birthdate, and introductory information. The interviewers also explained that the tape recorder, which was within view, was being used to help remember all the suggestions that the child made for improving the graph. In some cases, the interviewers read the items and distractors aloud, the child read them aloud, or, the child read them silently. This procedure was dependent upon the child's reading/decoding ability and whether the child preferred to read orally or silently. In some cases the interviewers gave the child feedback as to the correctness of the responses, in some cases the child was told the correct answer when he/she asked, and in some cases the child was corrected for misconceptions.

The graphs that were presented to the children were taken from the researcher-designed graph test used in the previous study (Curcio, Note 1), except for one graph which was redesigned. The questions accompanying each graph had been constructed to reflect three levels of comprehension: "reading the data," "reading between the data," and "reading beyond the data."[1] The first two questions of each graph required a simple reading of the data (either recognizing key words in the title or axes' labels). Questions 3 and 4 of each graph required children to interpret the graph by comparing pieces of information or integrating information. Questions 5 and 6 of each graph required children to extend the data or predict from the data.

All the students were presented with the "Average Time of Sunset" graph (see Figure 1) and a revision of the "Height of the Rodriguez Children in March, 1980" (see Figure 2). This revision was constructed in order to observe students' reactions to a format contrary to their expectations, contrary to what is seemingly "natural," and contrary to what they have been "traditionally" taught (Kosslyn, Note 2). The revision entailed rearranging the vertical axis so that the numbers were decreasing from bottom to top, and rewriting items 4 and 5. Although item 6 was used in its original form for the interviews (see Figure 2), it was recognized that a revision of this item is necessary because the original form has more than one "correct" answer (a and b). Therefore, the distractors for item 6 should be:

a. Pedro could never be that short for his age.

b. Pedro is much too tall for his age.

c. Pedro is of average height for his age.

d. Pedro is thin for his age.

Insert Figure 1 about here

Insert Figure 2 about here

Four fourth graders were presented with the graph entitled, "How Terry Spends a School Day" (see Figure 3), and four fourth graders were presented with the "Stamps Collected by Children" graph (Curcio, Note 1, p. 122). Five seventh graders were presented with "The Gross National Product during 1969 through 1979" (Curcio, Note 1, p. 119), and four seventh graders were presented with "The U. S. Government's 1981 Dollar Budget" (Curcio, Note 1, p. 113). The graphs were selected because a variety of graph-types was desirable, and, the level of difficulty had to be relative to the grade levels of the children.

Insert Figure 3 about here

Results and Discussion

Since the results are based upon a limited number of subjects, it is important to interpret the data collected with caution. This was our first attempt at a descriptive analysis employing an interview technique. Even though the sample was small, it seems as though this approach was fruitful because we were able to generate hypotheses to examine to what extent the results of this small-scale, exploratory study confirm the statistical results of the previous study (Curcio, Note 1).

Spiro (Note 3) suggested that for comprehension of general discourse to occur, a reader must draw on information from the text and from schemata. The coordination involves three major strategies: reliance on text information plus integrating it with prior knowledge; heavy reliance on text information in some instances; and finally, a heavy reliance on schema-based knowledge with only minimal reference to the text. It was found that children attempted to interpret and comprehend graphs in the same way.

Children who employ strategies that match the intended level of comprehension of the graph questions usually understand the message of the graph. On the other hand, errors in comprehension tend to occur primarily under two conditions (assuming adequate decoding ability). They occur when readers become overreliant on text-based information during a situation which requires the integration of background knowledge. They also occur when readers become too schema-based and cease to verify interpretations with text-based information. The interviews in this study revealed that students utilized all three correct answer strategies and also the two error strategies.

Text-/Schema-Based Comprehension Processing

In this case, the children were able to integrate the relevant information from the graph with relevant background knowledge. This was evident by children referring to particular aspects of the graph and describing how that information was used to obtain an answer.

Items that required "reading between the data" and "reading beyond the data" were designed to employ prior knowledge as well as referring to the information and data located in the graph. The results of the previous study (Curcio, Note 1) suggested that the mathematical relationships were embedded within the deep structure of the graph and topic, and graphical form cues for retrieving relevant prior knowledge were located in the surface structure of the graph. Many students who attempted items by referring to the graph and applying relevant prior knowledge answered the items correctly. How the students integrated information from the graph and brought their prior knowledge to bear are highlighted in the following example.

Example 1. (See Figure 3, item 5)

Interviewer: (reading item #5) *How many hours a week not including Saturday and Sunday did Terry spend on homework?*

S45: (pause) *Ten hours, c?*

I: *How did you figure out it was ten hours?*

S45: *Because I know there are five days in school and hours is two hours, so I go 5, 10, 15--. I mean 2, 4, 6, 8, and 10* (counting on fingers) . . .

I: *Right. That's--*

S45: *So one day, two hours, two days four hours, three days, six hours, and four days, eight hours, and five days is 10 hours.*

After extracting the necessary information from the graph (Terry spends two hours per day on homework) and bringing relevant prior knowledge to bear (there are five school days in a week, excluding Saturday and Sunday; and multiplication is an appropriate operation to employ--i.e., 2 x 5 = 10), S45 was able to derive the correct answer. This is an example of an item that was designed so that the child would "read beyond the data."

Text-Based Comprehension Processing

Strategies that yield the correct answer. In the children's descriptions or explanations they clearly referred to the graph by pointing to it or by remarking, "I found the answer right here on the graph." (It is important to note that in order to refer to the graph, knowledge of how to read the data directly from the graph was implicit; i.e., the children knew how to locate specific coordinates or refer to the axes' labels.)

Children who used text-based processing to respond to comprehension questions that required a simple "reading of the data," were usually successful in their responses. The only exception was in some cases, fourth graders had trouble matching vertical and horizontal data entries because guidelines (such as graph paper lines) were not provided.

The following is an example of text-based processing employed to respond to an item requiring a literal reading of the graph.

Example 2. (See Figure 1, item 2)

I: *All right. Number two.* (reading item #2) *4:35 P.M. is the average time of sunset during which month?*

S71: (pause) *December.*

I: *O.K., and how did you do that one?*

S71: *I looked at the graph.*

Strategies that yield incorrect answers. In general, it seems as though students are aware of the need to enact text-based processing strategies for this literal type of comprehension. However, students who employ text-based processing strategies for higher-level comprehension questions requiring them to "read between the data" and "read beyond the data," usually do not have enough information to respond to the questions successfully. Their reliance upon the text and failure to bring relevant prior knowledge to bear (whether it be knowledge about the topic, mathematical content, or graphical form) hinders their higher-level comprehension. Example 3 highlights this problem.

Example 3. (See Figure 3, item 5)

I: *O.K., number five, go ahead.*

S47: (reading item #5) *How many hours a week, not including Saturday and Sunday, does Terry spend on her homework? Two, a.*

I: *Why did you choose two?*

S47: *Because it says right here* (pointing to the graph) *he spends two hours a week on homework.*

In Example 3, S47 (as well as other students) did not bring essential prior knowledge of mathematical content to bear by multiplying two hours of homework per day by five days (seven days in a week minus two days for Saturday and Sunday). During the preliminary discussion about the graph, the student did recognize that the activities and time for each was during one day. One possibility is that S47 did not remember that the circle graph represented the time spent during *one* day, since reference is made to "a week" in the question. Another possbility is that the student had all the components but did not know what operation or what sequence of operations to perform in order to obtain the answer. The result in this case was that the student's information, obtained solely from the text, was inadequate in processing a task of comprehension designed to force utilization of prior knowledge.

Schema-Based Comprehension Processing

The interviews revealed three aspects of schema-based comprehension processing: not attending to the graph and relying solely upon one's prior knowledge; attenoing to the graph but the topic leads the reader astray; and, attending to the graph but inconsistencies are not recognized. These three aspects are considered and discussed in relation to some excerpts of the interviews.

Not attending to the graph and relying solely upon one's prior knowledge. The children described how they answered the questions by stating, "I did it without looking at the graph," or "I got the answer off the top of my head," or "You really just have to know [the vocabulary]."

Some children had such a rich knowledge base that the information in the graph was superfluous and not needed to answer some of the items that required "reading between the data," and "reading beyond the data."

In general, seventh graders were more successful at attempting to answer items solely based upon their background knowledge than fourth graders. Although more fourth graders attempted to answer questions without attending to the graph (7 out of 8 fourth graders as opposed to 4 out of 9 seventh graders), only two of the fourth graders were successful in selecting the correct answer (one admitted to guessing) and all four seventh graders were successful in their schema-based processing. Seventh graders seemed to have a better sense of when it was appropriate to rely on a schema-based strategy. In addition, perhaps fourth graders' reliance upon their prior knowledge of the topic of the graph (without attending to the graph itself), compounded with their inadequate prior knowledge, might explain why prior knowledge of the topic of the graph is a predictor of fourth-graders' graph comprehension ability (Curcio, Note 1).

The following is an example of how a seventh grader's prior knowledge enabled him to successfully answer the question without referring to the information in the graph.

Example 4. (See Figure 1, item 5)

I: *O.K., number five.* (reading item #5) *Which of the following graphs represents the average time of sunset from January to June that would make the above graph represent one complete year?*

S74: *One complete year, or just half?*

I: *One complete year.*

S74: (long silence) *It would be b.*

I: *O.K., what did you do to get b?*

S74: *I know that the amount of sunlight per day increases from January to June and then b was the only graph that showed an increase.*

I: *How do you know that it increases from January to June?*

S74: *I've seen the sunset get earlier during the year.*

I: *Did you need to use the big graph over here to figure out the answer?*

S74: *No . . .*

Some children attempted to answer questions that required an integration of the data in the graph (e.g., subtracting given quantities) by relying solely on their prior knowledge. As a result, their responses were incorrect. Example 5 highlights this problem.

Example 5. (See Figure 1, item 4)

I: *Let's look at number four.*

S42: (silent reading) *I think about three hours.*

I: *And, how did you get that?*

S42: *Because in the summer the days are long, and it's a very long time before it gets dark.*

I: *Um hmm. And why did you pick three hours instead of two-and-a-quarter or, why not one-and-a-quarter, or one-and-a-half for that matter?*

S42: (pause) *Because it isn't that long. That would be the time in the fall or in the winter.*

I: *Um hmm.* (pause) *Oh, I understand what you're saying. Did you need the picture to answer this question or did you just answer it off the top of your head?*

S42: *Off the top of my head.*

I: *If you were to refer to the graph, would you still say three hours or, would you change your mind?*

S42: (pause) *I would still say three hours.*

In Example 5, S42 admitted that the answer came "off the top of my head." When the interviewer asked the child to refer to the graph, no effort was made to do so. Instead, the child insisted upon sticking to the incorrect answer. It might be possible that in general, fourth graders are unable to distinguish between their prior knowledge and that which is applicable to the task at hand, and then switching to the graph to locate necessary information when the prior knowledge is inadequate.

Attending to the graph but the topic leads the reader astray. In this case, the children were overly concerned with the topic of the graph to such a great extent that their descriptions and explanations went off on a tangent; i.e., the discussion was somewhat related to the graph but the children were sidetracked by "pouring out" their prior knowledge about the topic. Some children had to rely upon concrete or situational experiences when attempting the tasks of comprehension. By approaching the tasks in this way, they became distracted or sidetracked by considering somewhat-related information. However, in most cases (8 out of 12), students' discussion became so far removed from the task at hand that they did not answer the items correctly. Example 6 highlights this point.

Example 6. (See Figure 1, item 5)

S48: *I'll take a.*

. . .

I: *All right, now tell me why you picked a. Why was that a better answer?*

S48: *Well, I still don't think the time* (pause) *the sunset is strictly at 8:30. I think that it might curve* *wrong--still might be a little bit daylight outside.*

I: *And so you said something about a curve just then. What was that about? What does it remind you of?*

S48: *Well, this curve right here reminds me of the way, like, the daylight's set now. It doesn't* (pause) *at the time that it should set, it doesn't go straightly dark, it's still just slightly a little bit daylight outside.*

I: *I see. And how does that remind you of a curve?*

S48: *When you have a straight line it is going to be dark immediately, but when you have a curve it takes a little bit longer.* (illustrating by gesturing)

I: *I see. Because it's sort of rounded or something?*

S48: *It's a little bit longer than a straight line.*

I: *O.K. How does this one, this graph, relate to this graph?* (comparing choice a with the main graph)

S48: *This one right here looks the same as this one.*

I: *Did that influence your choice at all?*

S48: *Not that much.*

In Example 6, the curve of the graph reminds S48 of the path the sun follows when setting on a given day. S48 then employed related, but incorrect schema information in attempting to bring meaning to the data in the graph. It seems as though this child was distracted from attending to both the surface structure and deep structure of the graph (i.e., the axes' labels, title, and mathematical content), which were required in answering this item.

Attending to the graph but inconsistencies are not recognized. In this case, the children made specific references to the graph but they were not flexible enough in their thinking to recognize information that might have been contrary or inconsistent with what they thought or had learned previously. In Piagetian terms, the children were probably able to assimilate the incoming information, but unable to accomodate it, i.e., make revisions in their already-established, relevant schemata.

Some children (7 who had low mathematics achievement scores) did not recognize inconsistencies on the revision of the "Height of the Rodriguez Children in March, 1980" (i.e., that the higher the bar, the shorter the person who is being represented). This is highlighted in Example 7.

Example 7. (See Figure 2, item 3)

I: *O.K., number three.*

S47: (reading item #3) *Who was the tallest?* (pause) *Pedro.*

I: *And why did you say that?*

S47: *Because his bar goes all the way up, the most . . .*

I: *O.K., why didn't you choose Jose, for number 3?*

S47: *Because this is not as big as this one. When you look for the tallest you look for which one is the highest . . .*

In some cases, students insisted upon following their intuition (i.e., that the higher the bar, the taller the person who is being represented) regardless of the contradictory information along the vertical axis. This is highlighted in Example 8.

Example 8. (See Figure 2, item 3)

I: *So looking at the picture, what answer would you give me?*

S44: *I would give you Pedro.*

I: *And if you looked at these numbers.* (pointing to the vertical axis) *would you still say Pedro?*

S44: *Yes.*

These observations seem to agree with Kosslyn (Note 2)--that children are not as flexible in accomodating incoming information that might be inconsistent or contrary to what they expected, or have previously learned. In general, seventh graders and fourth graders with high mathematics achievement scores were somewhat more flexible in handling this situation. They usually changed their answers to correspond to the numbers along the vertical axis. They made their changes after monitoring their own thinking, or after further questioning by the interviewer.

In some cases, children had inadequate prior knowledge of mathematical content. They might have responded to a graph question correctly, but for the wrong reason. The children do attend to the graph, and they do bring related prior knowledge to bear, but there is an essential link to connect the two that is missing. This incorrect reasoning that leads to a correct answer can be discovered by questioning children and having them think aloud. Example 9 highlights this approach.

Example 9. (See Figure 3, item 6)

I: *Let's look at number six.*

S42: (silent reading) *d, one-third?*

I: *Why?*

S42: *'Cause, because one-third is the largest?*

I: *Oh, O.K., how do you know one-third is the largest?*

S42: *Because one-twenty-one is very small, one-twelfth is small, and one-fifth is almost as small. One-third in this part is the largest.*

I: *And, why would that have to be the largest of all of them, I mean the answer to that question?*

S42: *'Cause all of them is small when you cut them into different sections, the one-third is the largest.*

I: *O.K., why, my question is, why would that have to be the largest? Why couldn't it be the smallest one that would be the answer to this question?*

S42: *Because when you have a circle and you cut it up into three parts, each one is about* (showing on the circle graph)

I: *Um hmm. Right, that's, what you're saying is correct. But, my question is why would the answer a, b, c, or d, the one that you pick, have to be the largest fraction, to this question--why would the answer have to be the largest of these choices and not the smallest and not the middle?*

S42: (long pause) *Because the smaller the number, the larger the fraction?*

I: *That's true, you're right, the smaller the number in the denominator the larger the fraction. . . But now with respect to this question, that says* (reading the item aloud)

What fractional part of a week, not including Saturday and Sunday, does Terry spend sleeping? Why would the answer have to be the largest fraction?

S42: *Because the larger, because sleeping is the largest thing there* (referring to the circle graph), *on the graph.*

I: *Um hmm.*

S42: *And on here it's the largest thing* (referring to the distractors).

I: *Oh, now I want to ask you another question. If I said, if one of these choices were one-half,* (pause) *is one-half now the smallest, or the largest, or you can't tell of all these fractions?*

S42: *The largest.*

I: *So if that was a choice, would you still say one-third, or, would you say now, one-half?*

S42: *One-half.*

In the above example, the child's comments indicate that schemata have been activated and prior knowledge was being brought to bear. Although S42 did bring knowledge to bear, the knowledge, which linked the largest portion of the circle graph with the largest fraction in the distractors, was an incorrect strategy to use. As was stated previously, the student had the right answer for the wrong reason. Questioning students in this way can help teachers focus on how children arrive at their answers. By using this approach, it become obvious that it might not be the "answer" that needs correcting, but rather "how" the answer was derived that needs correcting. This is in agreement with an observation made by Davis (Note 4).

Summary

The purpose of this small-scale, exploratory, descriptive study was to examine how children process different tasks of comprehension presented in graphical form. We attempted to relate the descriptive data to the results of the previous study (Curcio, Note 1). As previously mentioned, the results are to be interpreted with caution because the sample was small.

In summary, three types of processing strategies which led to both correct and incorrect responses (Spiro, Note 3) were utilized by students in answering questions. Most students were aware of the need for, and also used, a text-based strategy for "reading the data" directly from the graph. Most seventh-grade and higher achieving fourth-grade students demonstrated the text/schema integration strategy successfully on some problems. Seventh graders seemed to know when to rely on schema-based strategies, even when not required by the example, whereas fourth graders were less successful. A number of fourth graders and seventh graders failed to note, process, and/or adjust for inconsistent information on the redesigned graph on height.

The clear perceptual similarity between height and the vertical relationship of the bars as well as a schema for the usual form of this type of bar graph may have contributed to the intransigence of student response on this item. There is no reason for students to expect a "trick" format.

Their inflexibility in light of new information is somewhat reminiscent of the performance of the adults in the Anderson, Reynolds, Goetz, and Schallert (1977) study in a slightly different context. Subjects were given two ambiguous passages to comprehend. They also answered multiple choice questions with two possible correct answers based on the two interpretations. Even with exposure to cues for alternate interpretations, 62% of the subjects still failed to report awareness of a second interpretation of each passage.

It seems that once a schema is invoked and at least partially instantiated, there is strong resistence to change. Whether student performance on the height item is indicative of a developmental phenomenon as suggested by Kosslyn (Note 2) is an interesting hypothesis. It needs further testing using both children and adults and varying the type of graph and graph topic.

One issue that was raised in this study is the question of type of processing required by multiple choice questions. For example, on questions designed to test "reading between the lines," some students employed a schema-based strategy with little reference to the graph. It would be quite possible for researchers and/or practitioners to draw erroneous conclusions about processing on this type of item, unless the type of processing is verified. Depending upon the student's prior knowledge in relation to the question, the type of processing may differ for the same question (see Royer and Cunnigham, 1978 for a discussion of the role of background knowledge in testing).

Other researchers have used this type of interview technique successfully in mathematical problem-solving research. Clement (1982) has developed a model of problem solving to examine correct and incorrect interpretations of algebra word problems. The processes that yield incorrect interpretations are word-order-match and static comparison. By word-order-match Clement indicates a process which is triggered by a phrase in the text. The syntax of the English in the problem is misleading in terms of the "syntax" of the equation which must be written to solve it. The semantic, static comparison process is characteristic of students who seem to have all the pieces to solve the problem, but the answer is based upon one static erroneous interpretation. The third process, operational equality, yields a correct interpretation of the problem. It occurs when students have a clear ability to abstract from the wording of the problem to create an equation, integrating information from text and schemata successfully.

The strategies used by students in this study seem to fit the Clement model. In this study, errors caused by overreliance on a text-based strategy (when in fact this information is too limited by itself to bring meaning to the deep structure of the graph), may be similar to Clement's word-order-match process (see Example 3). His static comparison process might be related to a heavy reliance upon text-based processing or schema-based processing that limits the reader's ability to bring meaning to the deep structure of the graph (see Example 8). Finally, the process of operational equality might represent the proper balance between text-based and schema-based processing that contributes to high level cognitive processing, allowing the reader to bring meaning to the deep structure of the graph (see Example 1). Items, questions and interview protocols designed to test the validity of the Clement model in relation to graph comprehension should be created. Kosslyn and Pinker (Note 5) have identified certain semantic and syntactic components of graphs which might facilitate the design of such materials.

Future research should also consider the role of metacognition in graph reading. In some interviews it was observed that children were monitoring their comprehension (e.g., students caught errors in their thinking on their own or after probing by an interviewer). Since monitoring is a major part of metacognition (Brown, 1980), protocols should be designed that examine how novices (e.g., fourth graders) and older students monitor graph comprehension. If they do not spontaneously monitor when necessary, what kinds of cues and how many are needed to trigger monitoring followed by fix-up strategies? To what extent are students aware of what they are doing as they answer questions?

Finally, in some interviews it was obvious that children did not know when to employ text-based strategies, schema-based strategies, or a combination of both. Studies need to be conducted that explore (1) how children determine which strategy to use, and (2) whether the strategy employed is a function of reading achievement, mathematics achievement, prior knowledge or an interaction of any combination of these factors.

Reference Notes

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Footnote

[1]The idea for the three levels of comprehension was taken from P. D. Pearson and D. D. Johnson, in *Teaching reading comprehension.*

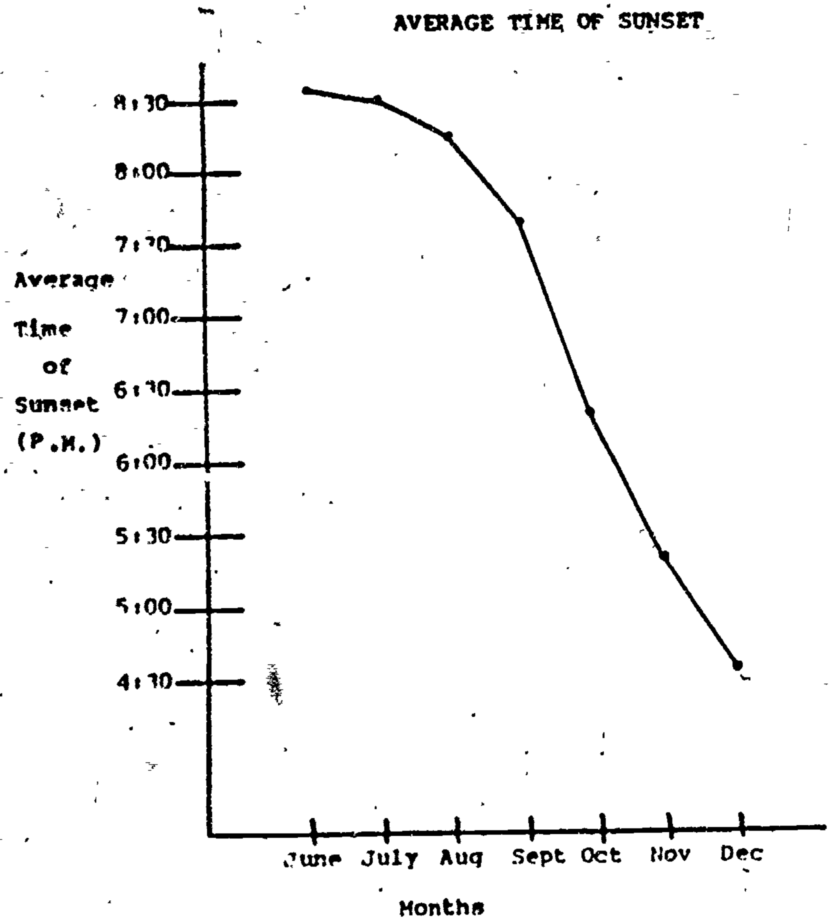
TABLE 1

Fourth- and Seventh-Grade Students' Reading and Mathematics Achievement Profiles

ID	Reading	Mathematics	ID	Reading	Mathematics
S41	High[a]	High	S71	Low[b]	Low
S42	High	High	S72	High	Low
S43	Low	Low	S73	High	Low
S44	High	Low	S74	High	High
S45	Low	High	S75	High	Low
S46	High	High	S76	High	Low
S47	Low	Low	S77	High	Low
S48	High	High	S78	Low	Low
			S79	Low	Low

[a] The median scores were used to determine high/low achievement. High reading = a raw score > 42 (the median score) on the SRA Reading Test, Level D; Low reading = a raw score ≤ 42. High mathematics = a raw score > 48 on the SRA Mathematics Test, Level D; Low mathematics = a raw score ≤ 48.

[b] The median scores were used to determine high/low achievement. High reading = a raw score > 55 on the SRA Reading Test, Level F; Low reading = a raw score ≤ 55. High mathematics = a raw score > 34; Low mathematics = a raw score ≤ 34.



USE THE GRAPH ABOVE TO ANSWER THE FOLLOWING QUESTIONS.

1. What is the average time that the sun sets in October?
   a. 5:00 P.M. c. 6:15 P.M.
   b. 5:15 P.M. d. 7:30 P.M.

   1. ____

2. 4:35 P.M. is the average time of sunset during which month?
   a. October
   b. November
   c. December
   d. January

   2. ____

3. As the months progress from June to December, which of the following is true about the average time of sunset?
   a. It gets earlier
   b. It gets later
   c. It remains the same
   d. It first gets earlier and then later

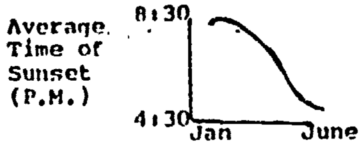
   3. ____

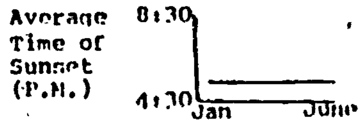
4. How much longer do you have to play outside (before it gets dark) in July, than you have in October?
   a. $1\frac{1}{4}$ hours c. $2\frac{1}{4}$ hours
   b. $1\frac{1}{2}$ hours d. 3 hours

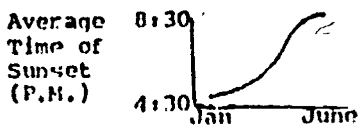
   4. ____

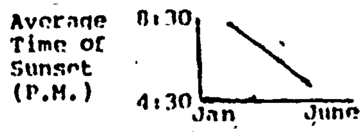
5. Which of the following graphs represents the average time of sunset from January to June, that would make the above graph represent one complete year?

   5. ____

a.


c.


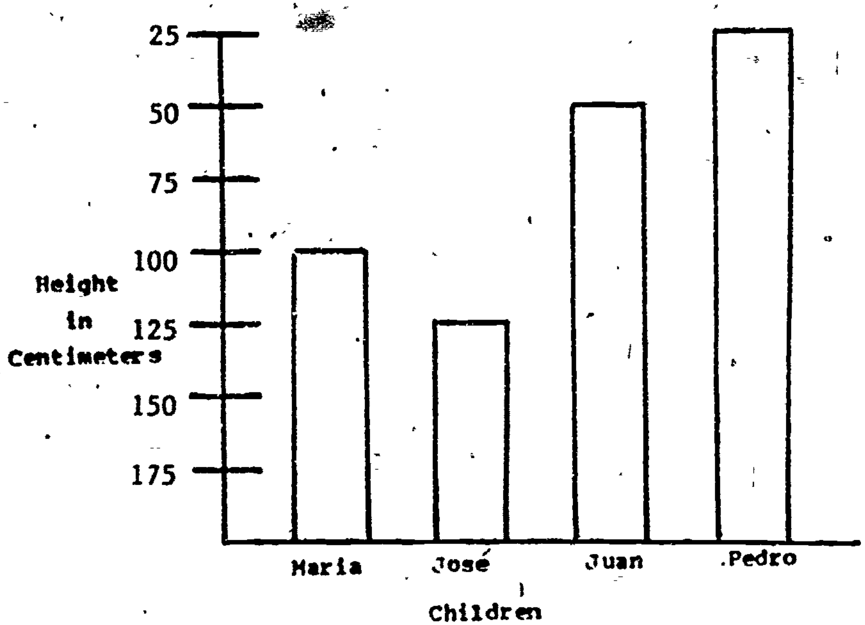
b.


d.


6. As the months progress from June to December, the average time of <u>sunrise</u> gets later. What do you expect to happen to the average number of daylight hours during this time?
   a. Increases
   b. Decreases
   c. Remains the same
   d. First decreases, and then increases

Figure 1. Copyright by F. R. Curcio, 1981

Revision of
HEIGHT OF THE RODRIGUEZ CHILDREN IN MARCH, 1980



USE THE GRAPH ABOVE TO ANSWER THE FOLLOWING QUESTIONS.

1. What does this graph tell you?
   a. The weight of the four Rodriguez children in March, 1980
   b. The grades of the four Rodriguez children in March, 1980
   c. The height of the four Rodriguez children in March, 1980
   d. The age of the four Rodriguez children in March, 1980

1. ___

2. How tall was Maria?
   a. 75 inches
   b. 100 inches
   c. 100 centimeters
   d. 125 centimeters

2. ___

3. Who was the tallest?
   a. Juan
   b. Pedro
   c. José
   d. Maria

3. ___

4. How much taller was José than Juan?
   a. 25 centimeters
   b. 50 centimeters
   c. 75 inches
   d. 75 centimeters

4. ___

5. If Maria grows 5 centimeters and José grows 10 centimeters by September, 1981, who will be taller, and by how much?
   a. Maria will be taller by 30 centimeters
   b. José will be taller by 30 centimeters
   c. Maria will be taller by 25 centimeters
   d. José will be taller by 25 centimeters

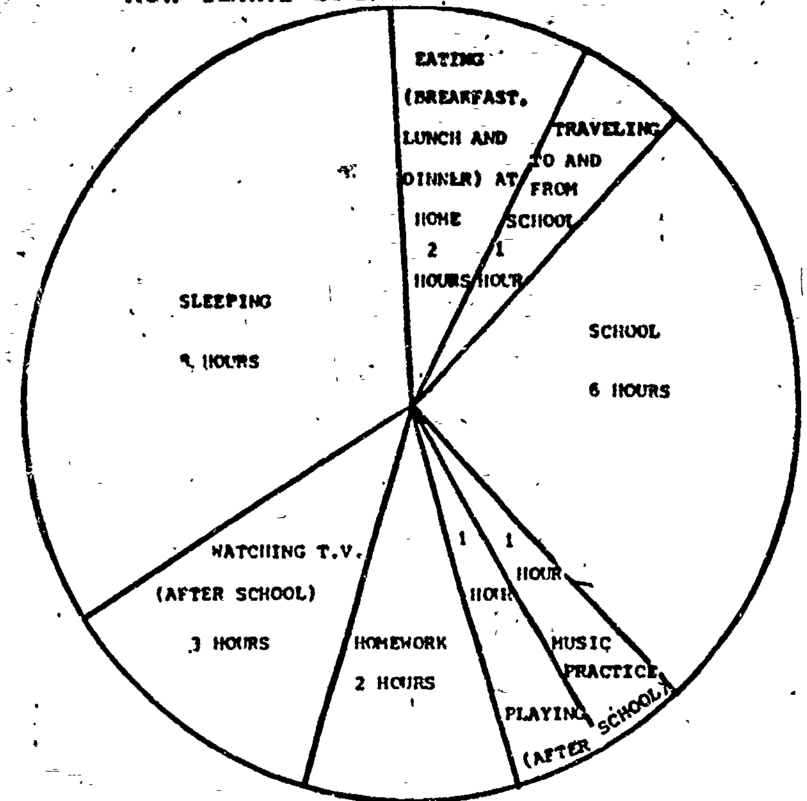
5. ___

6. If Pedro is 5 years old, which of the following is a correct statement?
   a. Pedro is much too short for his age
   b. Pedro could never be that tall for his age
   c. Pedro is of average height for his age
   d. Pedro is thin for his age

6. ___

Figure 2.

HOW TERRY SPENDS A SCHOOL DAY



USE THE GRAPH ABOVE TO ANSWER THE FOLLOWING QUESTIONS.

1. How many hours in one day does Terry spend in school?
   a. 2 hours
   b. 6 hours
   c. 8 hours
   d. 14 hours

1. ____

2. For which of the following does Terry spend three hours a day?
   a. Playing after school
   b. Eating
   c. Traveling to and from school
   d. Watching T.V.

2. ____

3. What does this graph tell you?
   a. Terry spends the greatest amount of time sleeping
   b. Terry spends the least amount of time in school
   c. Terry spends more time playing than watching T.V.
   d. Terry spends less time sleeping than in school

3. ____

4. What fractional part of a day does Terry spend in school?
   a. $\frac{1}{12}$ c. $\frac{1}{3}$
   b. $\frac{1}{4}$ d. $\frac{1}{2}$

4. ____

5. How many hours a week (not including Saturday and Sunday) does Terry spend on homework?
   a. 2 hours
   b. 8 hours
   c. 10 hours
   d. 14 hours

5. ____

6. What fractional part of a week (not including Saturday and Sunday) does Terry spend sleeping?
   a. $\frac{1}{21}$ c. $\frac{1}{5}$
   b. $\frac{1}{12}$ d. $\frac{1}{3}$

6. ____

Figure 3. Copyright by F. R. Curcio, 1981