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AUTHOR Curcio, Frances R.
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ABSTRACT

This study was designed to extend the schema-theoretic perspective of understanding general discourse to include graph comprehension. The sample included 204 fourth-grade and 185 seventh-grade pupils. Data were collected on achievement in reading and mathematics, sex, prior knowledge of topic, mathematical content, graphical form, and graph comprehension. Results indicated all independent variables, except sex, are unique predictors of graph comprehension for fourth graders. For seventh graders, unique predictors included mathematics achievement, reading achievement, and prior knowledge of content. There were no significant sex-related differences with fourth-grade pupils, but seventh-grade girls significantly out-performed boys in mathematics achievement. The results are viewed to imply that fourth graders focus their attention on a graph's surface structure, notably the topic and graphical form used. Seventh graders can scan graphs more effectively and become concerned with a graph's mathematical content. Implications for teachers are noted. (MP)

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THE EFFECT OF PRIOR KNOWLEDGE, READING AND MATHEMATICS ACHIEVEMENT, AND SEX ON COMPREHENDING MATHEMATICAL RELATIONSHIPS EXPRESSED IN GRAPHS

Final Report of a Study Funded by the
National Institute of Education

By

Frances R. Curcio
Project Director

Department of Education
St. Francis College
180 Remsen Street
Brooklyn, NY 11201

June 1981

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ABSTRACT

The purpose of this study was to extend the schema-theoretic perspective of understanding general discourse to include graph comprehension. The sample included 204 fourth- and 185 seventh-grade public school children. The data collection included achievement in reading and mathematics, sex, prior knowledge of topic, mathematical content, and graphical form, and graph comprehension. Separate correlation and regression analyses were performed to identify those factors which predict ability to comprehend graphs for fourth- and seventh-graders. t-tests were calculated to determine the significance of the difference between the means with respect to sex. Also, descriptive data were included in a supplemental analysis to highlight the statistical analysis.

The results indicated that all the independent variables, except sex, are unique predictors of graph comprehension for fourth graders. The unique predictors of graph comprehension for seventh graders included mathematics achievement, reading achievement, and prior knowledge of mathematical content. There were no significant sex-related differences between fourth-grade girls and boys. A change in achievement patterns was observed for young adolescents: seventh-grade girls significantly outperformed boys in mathematics achievement.

The results imply that fourth graders, who in general have a restricted global knowledge base, focus their attention upon the "surface structure" of the graph (i.e., the topic and graphical form). As highlighted in the interviews, this surface structure might distract them from attending to the message of the graph. Seventh graders can scan the graph more effectively and then become more concerned with the "deep structure" of the graph (i e., the mathematical content).

The conclusion of this report contains implications for teachers.

PREFACE

This study was the subject of my doctoral research and a major portion of this report (Chapter 1-5, Appendixes A-E) was submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at New York University (completed June, 1981). The last appendix, Appendix F, contains supplemental, exploratory data compiled and written with the assistance of Dr. M. Trika Smith-Burke, Associate Professor of Educational Psychology, New York University, to whom I am sincerely indebted for the great amount of time she spent sharing her expertise and knowledge.

All of the results of this report were based on a project supported by the National Institute of Education under grant No. NIE-G-80-0093. Supplemental funds were made available by the Faculty Research Committee of St. Francis College. Any findings, conclusions, and recommendations presented in this report are those of the author, and do not necessarily reflect the views of the National Institute of Education, nor St. Francis College.

F.R.C.

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I owe special thanks to Dr. Stephen M. Kosslyn, Department of Psychology and Social Relations, Harvard University, who served as a consultant for this project. By sharing his expertise, insights, suggestions, and ideas regarding his current research, he helped me to understand better the direction and focus of my own work.

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This project would not have been possible without my conscientious students, enrolled in the Teacher Training Program at Saint Francis College, who proctored and rated papers during the ten weeks of testing. Also, thanks are due to the members of the Office of Educational Evaluation, the Board of Education of the City of New York; Mr. Denis Fleming, Community Superintendent, District 20; the many principals, faculty and staff members, parents, and students whose willingness to cooperate and participate led to the success of this project.

Finally, I would like to express my sincere gratitude to the members of the National Institute of Education who deemed this project worthy of funding, and especially Dr. Susan Chipman who kept me informed of research on graph comprehension currently being conducted.

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CHAPTER I

THE PROBLEM AND ITS RELEVANCE

Introduction

The American public's dissatisfaction and concern have been aroused by the decline in students' performance in reading (Brandt, 1980; "Chicago Schools," 1978; "Connecticut Fails," 1980; Copperman, 1978, 1979; Fiske, 1978; Maeroff, 1978; McCarthy, 1979) and mathematics ("Connecticut Fails," 1980; Copperman, 1978, 1979; Gibney & Karns, 1979; Heyman, 1980; Maeroff, 1979; National Assessment of Educational Progress, 1979a). One of the factors that teachers have identified as hindering mathematics achievement is students' poor reading ability (Fey, 1979; Phillips, 1979). It may be possible that by being unaware of the specific reading skills necessary for success in a particular subject, teachers take for granted students' ability to perform many tasks that involve reading in the content areas.

Since the cry for "back-to-basics" has introduced great controversy, a wide range of meaning, and implications for curriculum development ("Back-to-Basics," 1977-78; Webb, 1977-78), the National Council of Supervisors of Mathematics (NCSM) issued a list of ten vital skill categories (NCSM, 1977). Reading, interpreting, and constructing graphs was identified as one of these vital skills. Also, it has been recognized that the ability to interpret information from graphs is a requirement for literacy (Bamman, Hogan, & Greene, 1961; Hogan, Farr, Prescott & Balow, 1978; National Assessment of Educational Progress, 1979b; Chipman, Note 1), and it is a component of school learning (Price, Martuza, & Crouse, 1974).

Although literal reading of data presented in graphical form is an important component of graph reading ability, the maximum potential of the graph is actualized when the reader is capable of interpreting and generalizing from the data presented (Kirk, Eggen, & Kauchak, Note 2). The results of the Second National Assessment of Educational Progress (NAEP) indicated that "students' ability to read graphs is superficial" (Bestgen, 1980, p. 27). Nine- and thirteen-year-old children were capable of answering low level cognitive items that required literal or direct reading of the graph (Bestgen, 1980; Carpenter, Kepner, Corbitt, Lindquist, & Reys, 1980), but students were less competent at tas[illegible] required high level cognitive skills, such as interpreting, integrating, generalizing, and extending the data presented in the graph (Bestgen, 1980; NAEP, 1979b). This deficiency was also recognized in the results of the first NAEP (NAEP, 1973). The importance of the ability to draw inferences and predict from data has been recognized by the National Council of Teachers of Mathematics (NCTM) by recommending "increased emphasis" on this activity (NCTM, 1980, p. 7).

It is possible that the advent of a "new" cognitive perspective for explaining reading comprehension (Chipman, Note 1; Smith-Burke, Note 3) can be used to help discover some of the reasons why students experience difficulty with reading graphs. At this time there is an inadequate understanding of how types of text, other than story-structured materials, are processed (Kintsch, 1977; Sticht, 1977). An exploration of how schema theory is related to reading mathematics (Silver, 1979) and mathematical understanding (Greeno, 1978) is warranted.

Schemata, the organized frames of knowledge which also contain "information about how this knowledge is to be used" (Rumelhart, Note 4, p. 3), are dependent upon past experiences, past knowledge, information and/or skills, called prior knowledge. It has been demonstrated that prior knowledge, or the lack of it, may cause multiple interpretations of ambiguous reading passages, as well as the ability or inability to interpret text material (Anderson, Reynolds, Schallert, & Goetz, 1977; Kintsch & van Dijk, 1978).

When this schema-theoretic concept of prior knowledge is applied to graph comprehension, three aspects of prior knowledge are apparent: prior knowledge of topic, prior knowledge of mathematical content, and prior knowledge of graphical form. First, Vernon (1946, 1950, 1952, 1953) hinted that unfamiliarity with the topic of the graph hindered comprehension. The topic, which is the subject of the graph, is one of the factors that should be taken into consideration when measuring graph comprehension (Bamberger, 1942). A second aspect of prior knowledge is mathematical content. Bamberger (1942), Goetsch (1936). and Vernon (1952) stated that comprehension of graphs was dependent upon students being familiar with the mathematical concepts, or mathematical content, employed in the graph. Hinsley, Hayes, and Simon (1977) and Silver (1981) recommended that structure, or form, be taken into consideration when examining students' mathematics schemata. In particular, a third aspect of prior knowledge, prior knowledge of the structure of the graph, or the graphical form, might also be a critical factor in the students' ability to interpret information presented in a visual display (Janvier, 1978; MacDonald-Ross, 1977).

The National Advisory Committee on Mathematical Education (NACOME) has recommended that studies be conducted to acquire knowledge about the relationships among experience, content, modes of expression, and student ability (NACOME, 1975). The purpose of the present study was to extend the schema-theoretic perspective of understanding general discourse to graph comprehension by examining the effect of prior knowledge of topic, mathematical content, and graphical form on the ability to comprehend the mathematical relationships expressed in graphs.

The relation among general reading, mathematics achievement and graph reading has not yet been clearly established. Some researchers maintain that reading graphs, like reading other mathematical text, is not limited to reading from left to right. Reading in other directions is essential to understanding (Bye, 1975; Carter, 1947; Hater, Kane, & Byrne, 1974; Krulik, 1980; Phillips, 1979; Simmons, 1977; Thomas & Robinson, 1977; Harlin, Note 5). On the other hand, despite the structural differences between the nonverbal, diagrammatic, pictorial format of graphs (NAEP, 1973), and prose text, other researchers (Herrmann, 1976; Johnson, 1971) have found a correlation between general reading performance and graph comprehension. Goetsch (1936), Herrmann (1976), and Johnson (1971) have also indicated that graph comprehension is correlated with mathematics achievement. Therefore, students' reading and mathematics achievement in relation to graph reading ability have also been examined in this investigation.

It has been suggested that males, in general, tend to be superior to females in mathematics, and that females tend to be superior to males in verbal ability (Armstrong, 1975; Guilford, 1967; Mullis, Oldefendt, & Phillips, 1977) and reading (Gonder, 1977; Mullis et al., 1977; NAEP, 1977). If these researchers' observations identify girls as better readers, are they better readers of graphs, or, if boys are better in mathematics, are they better at comprehending the mathematical relationships expressed in graphs? According to Peterson and Schramm (1954), no studies up to that date had indicated that sex would make a "difference in the accuracy with which graphs are read" (p. 187). Although Johnson (1971) analyzed boys' and girls' measures separately, no conclusions were made regarding the effect of sex on the ability to read graphs. However, her study included children from fourth- to sixth-grades, and in general, differences in mathematics achievement cannot be expected to be manifest at least until early adolescence, that is, at least the seventh grade (Armstrong, 1975; Fennema, 1978; Waters, 1980). Therefore, to identify whether there are any sex-related differences in graph reading ability in the present study, the sample included seventh-graders as well as fourth-graders.

The purpose of this study was to extend the schema-theoretic perspective of understanding general discourse to graph comprehension by examining the effect of prior knowledge on the ability to comprehend the mathematical relationships expressed in graphs. The effect of reading achievement, mathematics achievement, and sex were also included to identify the predictive factors which would be required for graph comprehension. It is hoped that the results contribute information which might provide the basis for diagnosing the factors which may impede graph comprehension.

The Questions Explored in this Study[1]

The following questions were explored in this study:

1. Is prior knowledge of topic related to comprehending the mathematical relationships expressed in graphs, independent of mathematics and reading achievement?

2. Is prior knowledge of mathematical content related to comprehending the mathematical relationships expressed in graphs, independent of mathematics and reading achievement?

3. Is prior knowledge of graphical form related to comprehending the mathematical relationships expressed in graphs, independent of mathematics and reading achievement?

4. Is reading achievement related to comprehending the mathematical relationships expressed in graphs, independent of mathematics achievement?

5. Is mathematics achievement related to comprehending the mathematical relationships expressed in graphs, independent of reading achievement?

6. Is sex related to comprehending the mathematical relationships expressed in graphs?

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[1]Another question originally proposed, "Is racial status related to comprehending the mathematical relationships expressed in graphs?" was deleted from the study. The reasons for deleting the racial status variable are discussed under The Sample, Chapter 3, page 52.

7. What is the optimal linear combination of the above-mentioned variables in terms of predicting comprehension of the mathematical relationships expressed in graphs?

Definitions

Comprehension

Comprehension consists of three tasks:

Task a represents the students' ability to "lift" the information from the printed page, merely reading the data. *Textually explicit* questions were used to assess students' ability in this task. "*Textually explicit* questions have obvious answers right there on the page" (Pearson & Johnson, 1978, p. 157). Students were required to select a written verbal description of the data using the terms in the title of the graph, expressing ideas using different words but keeping the meaning, or simply recognizing the required fact(s) in the graph.

Task b represents that part of comprehension that includes the interpretation and integration of presented information. This includes comparisons (e.g., greater than, greatest, tallest, smallest, etc.) and the use of other mathematical concepts and skills (e.g., addition, subtraction, multiplication, division). This is considered to be reading between the data. *Textually implicit* questions were used to assess the students' ability in this task. "Comprehension is regarded as *textually implicit if* there is at least one step of logical or pragmatic inferring necessary to get from the question to the response *and* both question and response are derived from the text" (Pearson & Johnson, 1978, p. 161).

Students were required to identify the mathematical relationships among data presented in graphical form.

Task c represents that part of comprehension that requires students to extend, predict, or infer from the data and/or tap existing schemata for information not present on, nor capable of being interpreted from the printed page. This is considered to be reading beyond the data. *Scriptally implicit* questions were used to assess students' ability in this task.

> Scriptal comprehension . . . occurs when a reader gives an answer that had to come from prior knowledge (it is not there in the text) to a question that is at least related to the text (that is, there would be no reason to ask the question if the text were not there). It is similar to textually implicit comprehension in that an inference is involved; however, it is different in that the data base for the inference is in the reader's head, not on the page. (Pearson & Johnson, 1978, p. 162)

Operationally, comprehension of the mathematical relationships expressed in graphs was a score achieved on a multiple-choice, reading-a-graph test designed specially for this study. (For further discussion, see Instrumentation, Chapter III, page 38, and Appendix A.)

Graphs

Graphs include the "coordinate representation of points, pictographs, bar graphs . . . line graphs" (Hogan et al., 1978, p. 100) as well as circle graphs (NAEP, 1979b). They "are often used to present numerical data and to show relative sizes or quantities in cases where exact facts or figures are not as important as an obvious presentation of the substances of the information" (Dominy, 1967, p. 5). Also, graphs

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facilitate "the presentation of facts for comparative purposes, and in many instances the graph indicates significant facts not obviously apparent in numerical form" (Arkin & Colton, 1940, p. 3).

The types of graphs used in this study were: bar graphs (also termed bar charts), circle graphs (also termed pie charts or pie diagrams), line graphs (also termed broken-line graphs), and pictographs (also termed pictorial graphs or pictograms).

Bar graphs. Representing it horizontally or vertically (depending upon a time variable), the bar graph allows the reader to compare discrete quantities expressed by rectangular bars whose heights (or lengths) are proportional to the quantities that they represent (Arkin & Colton, 1940). The bars are constructed within perpendicular axes. The axes are labelled.

Circle graphs. The area of the circle graph "is divided into segments [depicted by lines emanating from the center of the circle]. Each segment represents a proportionate part of the whole" (Arkin & Colton, 1940, p. 131).

Line graphs. A line graph is used to compare continuous data. Points are plotted within perpendicular axes to represent a functional relationship. The axes are labelled. The points are connected by straight or broken lines (Arkin & Colton, 1940).

Pictographs. The pictograph uses representative, uniform pictures to depict quantities of objects or people with respect to labelled axes (Arkin & Colton, 1940).

The four graph-types -- bar, circle, line, and pictograph, define

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"graphs" because these are the most common graphs encountered in the New York State (State Education Department, 1977) and New York City (Board of Education of the City of New York, 1962, 1979) mathematics curricula. These four types of graphs are also the basic forms found in daily newspapers and magazines.

Mathematics Achievement

Mathematics achievement is a level of functioning, indicating the amount of mathematics the child has learned. Operationally, mathematics achievement was defined as the total score (including computation and concepts) received on the *SRA Achievement Series* - Mathematics, Level D (for fourth-graders) and Level F (for seventh-graders). (For further discussion, see Instrumentation, Chapter III, page 50.)

Native-English-Speakers

Native-English-speakers are students who speak only English at home, i.e., they are not bi- or multi-lingual. (For further discussion, see The Sample, Chapter III, page 52.)

Prior Knowledge

Prior knowledge is experience, knowledge of a topic or situation, information and/or skills that have been previously acquired by the subject (Pearson & Johnson, 1978). These past experiences, knowledge, information and/or skills are added, integrated, stored, and catalogued into existing schemata (Kamil, Note 6). Prior knowledge is not necessarily a product of formal schooling. Operationally, prior knowledge was subdivided into three parts:

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Prior knowledge of topic. This subtest contained items that reflected the vocabulary and general schema of subject-matter information assumed to be needed to comprehend the graph test items.

Prior knowledge of mathematical content. This subtest contained items that reflected the mathematical skills and knowledge needed to respond to the graph questions.

Prior knowledge of graphical form. This subtest contained items that reflected content-free, graph-reading skills required for responding to bar graph, circle graph, line graph, and pictograph items.

(For further discussion of the Prior Knowledge Inventory and its subtests, see Instrumentation, Chapter III, page 47, and Appendix B.)

Reading Achievement

Reading achievement is a level of functioning, indicating the grade level at which the child has achieved reading competence. Operationally, reading achievement was defined as the total score (vocabulary and comprehension) received on the *SRA Achievement Series* - Reading, Level D (for fourth-graders) and Level F (for seventh-graders). (For further discussion, see Instrumentation, Chapter III, page 50.)

Schemata

Schemata "are data structures for representing the generic concepts stored in memory" which are represented by stereotypes (Rumelhart & Ortony, 1977, p. 101). They are organized units of knowledge, as well as "information about how this knowledge is to be used" (Rumelhart, Note 4, p. 3). Within each schema are hierarchies of embedded schemata and sub-schemata (Rumelhart & Ortony, 1977).

CHAPTER II

THEORETICAL RATIONALE AND RELATED RESEARCH

In order to attempt to extend the schema-theoretic perspective of comprehending general discourse to comprehending mathem cical relationships expressed in graphs, and to examine whether sex is a factor contributing to graph comprehension, a review of the literature pertinent to the study is presented in this chapter dealing with Schema Theory and Comprehension, Graphs, and Sex-Related Differences in Mathematics and Reading.

Schema Theory and Comprehension

One of the earliest appearances of the concept of "schema" was over two hundred years ago in Immanual Kant's *Critique of Pure Reason* (Kant, 1781/1966). In this tradition, researchers and cognitive psychologists have coined terms such as "frames" (Kuipers, 1975; Minsky, 1975; Winograd, 1975), "scripts" (Schank & Abelson, 1977), and "schemata" (Adams & Collins, 1977; Anderson, 1977a, 1977b; Bartlett, 1932/1977; Bobrow & Norman, 1975; Head, 1920; Piaget, 1952/1963; Rumelhart & Ortony, 1977; Rumelhart, Note 4). Although these terms have particular technical differences (Rumelhart, Note 4), they are currently being used interchangeably to refer to the same general concept of knowledge in memory (Petrie, 1977; Davis, Note 7). Without loss of generality, the schema-theoretic framework has been used in this study because past and current research has applied it in exploring problems in education.

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Schemata, which are stored in long-term memory, represent knowledge and directions for how these schemata are used (Kieras, 1977; Rumelhart & Ortony, 1977). They aid in comprehension by helping readers/listeners make sense out of what is being presented (Adams & Collins, 1977; Brown, Smiley, Day, Townsend, & Lawton, 1977), and by allowing additions to the knowledge already stored in memory (Spiro, 1977). During the process of comprehension, readers/listeners may clarify, modify, revise, edit, amend, and/or extend that which has previously been learned.

The Role of Prior Knowledge

The cognitive or affective response that is stimulated by the relationship of the abstract word to the abstract idea is heavily dependent upon the readers' experience (Kealy, Note 8). How readers perceive the incoming information is related to the prior knowledge stored in memory (Bartlett, 1932/1977; Bransford, Nitsch, & Franks, 1977). In particular, to comprehend the message within a text, readers tap their schemata, thus locating related background experiences. These experiences are then activated to bring meaning to the printed page (Adams & Collins, 1977; Brown et al., 1977). Each schema contains a framework of knowledge for analyzing, assimilating, or accomodating incoming information. The framework is characterized by slots or holes which leave the schema incomplete (Royer, 1978). When slots remain unoccupied, comprehension is impeded (Anderson et al., 1977; Royer, 1978). During reading or listening, the information needed to satisfy or fill the slots or holes may be found and inserted (thus facilitating comprehension).

Once the slots or gaps are satisfied with information, a schema is

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said to be instantiated. Instantiation may occur through the use of information in memory or by default (Rumelhart & Ortony, 1977). Default assignments, which consist of pattern completions contrived by one's imagination (Minsky, 1975), operate either to correctly or incorrectly satisfy the existing gap to facilitate comprehension (Davis, Note 7). As schemata become specialized and instantiated, default procedures and assignments become constrained (Rumelhart & Ortony, 1977) and unnecessary. After a schema is instantiated, and the subject is presented with a related but novel situation:

> The information that matches slots in the schema would be said to be significant, whereas information that does not would be called unimportant, irrelevant, or -- in the limiting case -- incongruous. Information that fits the superordinate schema is more likely to be learned and remembered, perhaps precisely because there is a niche for it. It follows that one schema can provide slots for more of a certain fixed body of information than other schemata. If the knowledge domain were specified, it should be possible to make qualitative as well as quantitative predictions about just which details will be learned. (Anderson, Spiro, & Anderson, 1978, p. 434)

Research has been conducted which demonstrates the role of background knowledge in comprehension. Anderson et al. (1977) organized two groups of college students according to their physical education or music background. Two purposely ambiguous passages, each designed to have at least two interpretations, were constructed and presented to the students. Each group of students interpreted the passages consistently with members' background experience. It was concluded that "the interpretation people give to messages is influenced by their backgrounds" (Anderson et al., 1977, p. 376), and

> that many problems in reading comprehension are traceable to deficits in knowledge rather than deficits in linguistic skill narrowly conceived; that is, that young readers sometimes may not possess the schemata needed to comprehend passages. Or, they may possess relevant schemata but not know how to bring them to bear. Or, they may not be facile at changing schemata when the first one tried proves inadequate; they may, in other words get stuck in assimilating text to inappropriate, incomplete, or inconsistent schemata. (Anderson et al., 1977, p. 378)

In a recent study, Sjogren and Timpson (1979) replicated the work of Anderson et al. (1977) and examined the effects of prior knowledge with respect to sex and interests of the participants. Sjogren and Timpson (1979) recognized that the Anderson et al. (1977) study was confounded with sex, since all the members of the physical education group were males and all the members of the music group were females. Sjogren and Timpson (1979) found that sex and interests (determined by the students' major fields) of the students were related to the interpretation given to the ambiguously worded passages. In another replication study, reiterating the influence of prior knowledge on the ability to comprehend text, Carey, Harste, and Smith (1981) varied the environment (students were tested in music, physical education, and other classes), and concluded that context-of-situation is also a contributing factor in interpreting ambiguously worded text. In summary, the studies that highlighted the influence of prior knowledge on reading comprehension confirm Aaron's (1965) observation, i.e., prior knowledge contributes to comprehension. However, more recent studies suggested that comprehension might be further enhanced by considering the readers' interest and sex, as well as the context-of-situation in which the reading selection is presented.

Some studies have identified an apparent influence of background knowledge on the ability to answer reading comprehension questions presented to subjects without the companion passage (Pryczak, 1972; Pichert cited in Royer & Cunningham, 1978; Tuinman, 1973-1974). Subjects presented with multiple choice questions from standardized reading comprehension tests were able to respond correctly without having to read the companion passages. The validity of such reading comprehension tests must be questioned (Tuinman, 1973-1974) -- what is the purpose of having the paragraph if it is not needed to answer the accompanying questions? But, as previously mentioned, since prior knowledge enhances and facilitates comprehension, the role of background or prior knowledge, cannot be ignored. Test items should reflect the companion passage and tap the reader's prior knowledge base.

Prior Knowledge of Topic, Content, and Form

Knowledge of the topic, content, and form of general discourse is dependent upon the amount of previous meaningful exposure the reader/listener has had. A reader who confronts a text with an unfamiliar topic will not have a frame to help organize and interpret the information (Kintsch & van Dijk, 1978). Being aware of the topic of a passage (in some cases the topic is identified by the title of the passage) helped readers to retrieve relevant background knowledge and bring it to bear. This enabled the readers to comprehend and remember details in the text (Pichert & Anderson, 1976; Sjogren & Timpson, 1979). On the other hand, students who were given ambiguous passages without titles to help identify the subsuming schema, were not as successful at comprehending the passages as their counterparts, who were given the same passages with titles (Pichert & Anderson, 1976; Sjogren & Timpson, 1979).

A second aspect of prior knowledge, prior knowledge of content, represents knowledge of relationships between and among words and ideas. For example, understanding a text with anaphoric relations depends upon the readers' prior knowledge of referential cues which should enable them to link the pronoun being used with the term that it replaces (Pearson & Johnson, 1978). Also, understanding causal relationships expressed explicity or implicitly (Pearson & Johnson, 1978), requires prior knowledge of content. If stated explicitly, the link between cause and effect is evident to the reader who is familiar with the signal words employed in the statement(s). If stated implicitly, the link is not as evident and prior knowledge of content is required to infer the consequential link between (or among) two or more statements.

Individuals confronted with text materials to read must be familiar not only with the topic and content, but also with the framework, structure, or form of the content, and the conventions employed within the structure (Royer & Cunningham, 1978). These "form" schemata provide the basis for predicting the kind of structure and information inherent in certain types of discourse (Kintsch, 1977), and are prerequisites for comprehending similar but novel representations of information. For example, Stein (1978), who worked with first- and fifth-graders, concluded that children's expectations of story structure and how the text fulfills their expectations contributed to comprehending the story.

Prior knowledge is important to consider because the author does not put all the information in written discourse (Brown et al., 1977; Reder,

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1980; Schank & Abelson, 1977; Kamil, Note 6). That is, even though the incoming information might not be explicit enough to fill the gaps in the schemata of some readers, comprehension can still be achieved if there is an adequate storage of relevant background knowledge (Wittrock, 1973), specifically, prior knowledge of topic, content, and form. Therefore, if students are to be successful in comprehending general discourse, knowledge of the topics, content, as well as familiarity with the form and language (Reder, 1980; Smith-Burke, Note 9) of the discourse must be developed, reviewed, and cultivated. If there are any deficiencies in related prior knowledge, comprehension might be impeded.

Schema Theory Extended to Graph Comprehension

Similar to general discourse, graphs presumably also employ a schema which contains slots for certain aspects of the graph. The topic of the graph, which is identified by the title and the axes' labels, may be one of the factors for which prior knowledge is necessary for comprehending the mathematical relationships expressed in graphs. The mathematical content of the graph, including number concepts, relationships and fundamental operations, may be another factor for which prior knowledge is necessary to aid in comprehending the message of the graph. Finally, the graphical form (restricted to bar graphs, circle graphs, line graphs, and pictographs in this study) may be a third factor for which prior knowledge is necessary for successful comprehension of the mathematical relationships expressed in graphs. This study examined all three factors.

Graphs

The modern graph evolved from the work of René Descartes (Arkin & Colton, 1940). For the mathematician, the graph is "an invaluable aid in the solution of arithmetic and algebraic problems, the solution of mathematical formulas, and the representation of relationships" (Arkin & Colton, 1940, p. 4). For the lay person, the graph is an aid for clarifying, organizing, and summarizing text material found in newspapers, magazines, and advertisements.

Many mathematical concepts and skills are needed and can be developed by communicating ideas using graphical forms (Smith, 1979; Sullivan & O'Neill, 1980; van Engen & Grouws, 1975). In order to be successful in mathematics, the ability to interpret information from a graph must be cultivated (Eagle, 1948). However, the ability to read and interpret graphs is a skill not limited to the study of mathematics (Fay, 1950; Goetsch, 1936; Harper & Otto, 1934; Janvier, 1978; Smith, 1979; Strickland, 1938/1972; Weintraub, 1967; Wrightstone, 1939).

Purposes of Some Graph Studies

The studies of researchers whose articles were reviewed were quite diverse. Some of the purposes of these studies were as follows:

1. To examine the relative effectiveness of summarizing data using different graphical forms (Carter, 1947; Croxton & Stein, 1932; Culbertson & Powers, 1959; Feliciano, Powers, & Kearl, 1963; Goetsch, 1936; Malter, 1952; Peterson & Schramm, 1954; Strickland, 1938/1972; Thomas, 1933; Turner, 1974; Vernon, 1946, 1950, 1952; Washburne, 1927a; Wainer, Note 10);

2. To identify achievement/aptitude factors as possible predictors of graph reading ability (Culbertson & Powers, 1959; Herrmann, 1976; Johnson, 1971);

3. To examine the effect of instruction on demonstrating graph reading skills (Bamberger, 1942; Harper & Otto, 1934; Herrmann, 1976; Janvier, 1978; Johnson, 1971; Malter, 1952);

4. To examine the ability to retain information presented in graphical form (Herrmann, 1976; Price et al., 1974; Vernon, 1946, 1950, 1951, 1952; Washburne, 1927a, 1927b);

5. To identify factors contributing to graphical interpretations (Janvier, 1978);

6. To examine reading comprehension of text material accompanied by graphs (Feliciano et al., 1963; Harper & Otto, 1934; Turner, 1974; Vernon, 1950, 1951; Washburne, 1927a);

7. To examine how graphical information is encoded (Price et al., 1974).

Populations of Some Graph Studies

The populations in the research studies reviewed were also quite diverse. Adults (Feliciano et al., 1963; Peterson & Schramm, 1954; Vernon, 1946, 1952), college students (Carter, 1947; Culbertson & Powers, 1959; Feliciano et al., 1963; Price et al., 1974; Vernon, 1946, 1952), high school students (Culbertson & Powers, 1959; Feliciano et al., 1963; Janvier, 1978; Vernon, 1950, 1951), and elementary and/or intermediate school children (Bamberger, 1942; Goetsch, 1936; Harper & Otto, 1934; Johnson, 1971; Strickland, 1938/1972; Thomas, 1933; Turner, 1974;

Vernon, 1952; Washburne, 1927a; Wainer, Note 10) have been the subjects tested and studied.

Children in the fourth grade and seventh grade made up the sample in the present study because it is by fourth grade that most of the preliminary, elementary work with graphs should have been accomplished (Board of Education of the City of New York, 1962), as well as the fact that by the fourth grade, children should have achieved a sufficient command of reading and arithmetic skills, the tools of learning, necessary for graph reading (Strickland, 1938/1972). It is expected that the developmental growth and achievement in graph reading ability would be identified by the seventh-graders (Bamberger, 1942), and if sex-related differences do exist, they might become manifest at this time (Armstrong, 1975; Callahan & Glennon, 1975; Fennema, 1974a, 1977, 1978; Maccoby, 1966b; Suydam & Reidesel, 1969).

Types of Graphs Studied

Many of the research studies concerned with graph reading have incorporated many different types of elementary graphs, such as circle graphs, bar graphs, line graphs, and/or pictographs (Culbertson & Powers, 1959; Feliciano et al., 1963; Goetsch, 1936; Harper & Otto, 1934; Johnson, 1971; Peterson & Schramm, 1954; Strickland, 1938/1972; Thomas, 1931; Vernon, 1946, 1950, 1952; Washburne, 1927a; Wainer, Note 10) and some have included ramifications and/or more complex designs of these basic forms (Bamberger, 1942; Culbertson & Powers, 1959; Herrmann, 1976; Janvier, 1978; Johnson, 1971; Peterson & Schramm, 1954; Price et al., 1974; Turner, 1974; Vernon, 1946, 1950, 1951, 1952; Washburne, 1927a).

The four elementary graph-types are the most common graphs encountered in the New York State (State Education Department, 1977) and New York City (Board of Education of the City of New York, 1962, 1979) mathematics curricula. Therefore, the types of graphs used in this study were: circle graphs, bar graphs, line graphs, and pictographs.

Assessment of Graph Comprehension

Some of the studies reported contained examples of graphs and the test items used to assess graph comprehension. For the most part, the levels of comprehension measured in each test reflected "task a" (requiring a literal reading of the data, title, or axes' labels) and "task b" (requiring comparisons and the use of mathematical concepts and skills to read "between the data"). "Task c" items (requiring an extension, prediction, or inference dependent upon prior knowledge to read "beyond the data") were not commonly used. For example, Herrmann (1976) used only one multiple-line graph (designed without a title), accompanied by a 21-item test. The items reflected only "task a" (10 items) and "task b" (11 items). Johnson (1971) designed six graphs which were used as the pretest and the posttest. She constructed two circle graphs, one line graph, one pictograph, and two bar graphs. Each graph was accompanied by seven to nine items. Out of a total of 40 items, 32 would be classified as "task b" items.

Some of the commerically available mathematics tests that include graph items also concentrated on testing "task a" and "task b" levels of comprehension. For example, sample graph items on NAEP examinations included a comparison of two circle graphs accompanied by two "task a" items and one "task b" item, and a line graph accompanied by one "task a" item and two "task b" items (NAEP, 1979b). Also, the two graphs on the Mathematics subtest of the *Metropolitan Achievement Tests*, Advanced Form JS, are multiple-bar and muliple-dot graphs. The five items (two and three respectively) are "task b" items (Prescott et al., 1978). The two graphs on the Mathematics Concepts and Applications subtest of the *California Achievement Tests*, Book 14C, are a pictograph and a bar graph (Tiegs & Clark, 1979). The three items for the pictograph are "task a" (two items) and "task b" (one item). The two items for the bar graph are "task a" (one item) and "task b" (one item).

A schema-theoretic approach to assessing comprehension would include textually explicit (task a), textually implicit (task b), as well as scriptally implicit (task c) levels of comprehension (Pearson & Johnson, 1978) so that the test items reflect the companion text as well as tap the readers' prior knowledge base. Also, with respect to graph reading ability, desirable skills that should be acquired by children include both interpreting *and* generalizing from the data presented (Kirk, Eggen, & Kauchak, Note 2). Therefore, in this study, questions reflecting the three tasks of comprehension (task a, task b, and task c) were used consistently with each of the graphs.

Observed Deficiencies of Past Research

With such vast differences among purposes of research studies, target samples, and types of graphs and test items used, any universal, conclusive statement regarding graphs and graph reading ability would be presumptuous. With the exception of Janvier (1978), Price et al., (1974), and a study presently being conducted by Consulting Statisticians, Inc. (Note 11), the role of cognitive factors in processing the information presented in graphical form has received very little attention. Also, there were certain problems related to design, methodology, and reporting of some of the earlier research. For example, MacDonald-Ross (1977) has questioned the validity and reliability of Vernon's (1946, 1952) early work because no samples of the table, graph and histogram were available to compare with the examples of the statistics cited, and the statements of results in the text are confusing when compared to the information in the tables presented (Vernon, 1946, 1950). Vernon's (1946, 1950, 1951, 1952, 1953) as well as Washburne's (1927a, 1927b) studies have been criticized because their results may have been confounded with many unaccounted cognitive components (Consulting Statisticians, Inc., Note 11). Some of the graphs used by Vernon (1946, 1950, 1951, 1952, 1953) and Washburne (1927a, 1927b) were not constructed properly (MacDonald-Ross, 1977; Strickland, 1938/1972).

Prior Knowledge of Topic, Mathematical Content, and Form in Relation to Graph Comprehension

Despite the weaknesses of the above-mentioned studies, they provided evidence to suggest the importance of different aspects of prior knowledge for graph comprehension. Several studies considered the issue of prior knowledge of topic, either using topics expected to be unfamiliar to the subjects or topics known by all children. One approach attempted to control for prior knowledge of topic by using graphs with unfamiliar topics. For example, Washburne (1927a) selected the topic of his graphs and accompanying text to deal with the èconomic history of Florence. He selected this topic because he assumed that the subject would be equally unfamiliar to all the students. Vernon (1950) selected information dealing with unfamiliar topics (population and mortality statistics) because she also assumed that the majority of those tested would not have knowledge of these topics.

A second approach attempted to limit the amount of prior knowledge needed to interpret graphs by using topics that reflected an expected common knowledge base. For example, the test designed by Harper and Otto (1934) was composed of only literal level questions based upon facts from the curriculum. In another study, Culbertson and Powers (1959) requested students to answer questions only based on information in the graphs, not from their background knowledge. However, it is questionable that students are aware and capable of differentiating between their background knowledge and the isolated, literal information presented in the text (Brown et al., 1977).

A third approach attempted to prepare children for graph tasks to be encountered by providing them with experiences to build their prior knowledge base. For example, Strickland (1938/1972) found it necessary to have teachers spend two weeks on building a background for the graphs. The preparation activities included teaching units with suggestions for historically developing the topics of the graphs to be presented, discussion periods for children to express their own experiences, literature and reading periods for children to expand their personal experiences, trips and field observations related to the topics of the graphs.

Must the graph reader be familiar with the underlying mathematical concepts, or content, expressed in the relationships represented in graphical form? Goetsch (1936) indicated that a prerequisite for effective graph reading is a command of arithmetic. More specifically, the difficulty encountered by Vernon's (1952) subjects who read graphs depicting vital statistics (population and mortality rates), was attributed to an inadequate command of the underlying mathematical concepts (including ratio and percent) embedded in the graphic representation of the data. Similarly, the mathematical content embedded within the relationships expressed in the graphs used by Thomas (1933) was the cause of graph comprehension problems encountered by some of the younger children.

Other studies suggest the importance of the form or structure of the graphs. Gropper (1963), Janvier (1978), and MacDonald-Ross (1977) indicated that individuals approach their tasks of graph reading, or visual discrimination, with varying degrees of related prior knowledge. Comprehending graphic displays is dependent upon the readers' ability to distinguish and discriminate among sizes, shapes, and directions. This visual discrimination ability develops through relevant past experiences encountered with physical objects and events (Gropper, 1963). Also, having a repertoire of graphical forms stored in one's background knowledge and being capable of bringing it to bear, contributes to the reader's ability to comprehend the message in the graph (Janvier, 1978). Prior knowledge of graphical form may be a critical factor in the subject's ability to interpret the information in a visual display (Janvier, 1978; MacDonald-Ross, 1977).

Reading and Arithmetic Achievement in Relation to Graph Comprehension

Other studies have found that general reading performance and the general ability to do arithmetic are correlated with comprehending messages in graphs (Goetsch, 1936; Herrmann, 1976; Johnson, 1971). Goetsch (1936) identified fifteen frequently used skills for graph reading, but in order to use these skills students must "have a command of the fundamental reading skills, and . . . have a command of the fundamental arithmetic skills" (p. 83). Herrmann (1976), who tested fifth-graders, was concerned with the effects of training students to read multiple-line graphs. The *Iowa Test of Basic Skills* and a researcher-made multiple-line graph was administered to the children. The correlations between the scores on the multiple-line graph test and the reading and arithmetic subtests ranged from .40 to .54 (for subjects who were not trained in graph reading and who were able to refer to the graph to answer test questions). Johnson (1971) tested fourth-, fifth-, and sixth-graders. The *Gates-MacGinitie Reading Test*, the arithmetic subtest of the *California Achievement Test*, and a researcher-made graph test, among other tests, were administered to the children. She found the correlation between the scores on the graph test and the scores for reading performance and arithmetic to range from .54 to .73 (for all cases within each grade level). She also stated that "The findings of this study would appear to indicate that ability in arithmetic is more closely related to graph reading ability than is general intelligence and reading ability" (p. 105). However, since a measure of arithmetic achievement was used, the phrase, "achievement in arithmetic" should have been used rather than "ability in arithmetic." This study has attempted to identify the relative importance of prior knowledge of topic, prior knowledge of mathematical content, and prior knowledge of graphical form with respect to comprehending the mathematical relationships expressed in graphs, independent of reading and mathematics achievement.

Sex-Related Differences in Mathematics and Reading

Some researchers have recognized that males tend to be superior to females in mathematics (Armstrong, 1975; Lamott, 1977; Maccoby & Jacklin, 1974; Mullis et al., 1977; Rappaport, 1978; Sadker, Sadker, & Hicks, 1980; Woody, 1931) and analytical ability (Armstrong, 1975), and that females tend to be superior to males in verbal ability (Armstrong, 1975; Lamott, 1977; Maccoby, 1966b; Maccoby & Jacklin, 1974; Mullis et al., 1977) and reading (Asher, 1977; Gates, 1961; Gonder, 1977; Mullis et al., 1977; NAEP, 1977).

Reasons given for these academic differences included:

1. Cultural norms for viewing sex roles (Aiken, 1974; Brozan, 1981; Callahan & Glennon, 1975; Ernest, 1976; Fauth & Jacobs, 1980; Fennema, 1974b; Fennema & Sherman, 1976, 1977; Fox, 1977, 1981; Johnson & Greenbaum, 1980; Lamott, 1977; Rappaport, 1978);

2. Brain development and functioning differ between the sexes (Aiken, 1975; "Are Boys Better," 1980; Lamott, 1977; Restak, 1979);

3. Sex hormones influence intellectual activity (Aiken, 1975; Lamott, 1977);

4. Sex-linked, recessive gene transmission of intellectual ability (Aiken, 1974, 1975; Fennema, 1974b; Lamott, 1977; Maccoby & Jacklin, 1974);

5. Spatial-visual development might be more advanced in males (Burton, 1979; Fennema, 1974b, 1975, 1977, 1978, 1980a; Maccoby, 1966b; Maccoby & Jacklin, 1974; Restak, 1979; Sells, 1980);

6. Socio-economic status (Fennema, 1977; Fennema & Sherman, 1977; Maccoby & Jacklin, 1974);

7. Test items on achievement and ability tests, and school-related tasks might be sexually biased, that is, content might be male-oriented (Fox, 1977; Graf & Riddell, 1972; Janvier, 1978; Leder, 1974; Schonberger, 1978), or female-oriented (Asher, 1977; Johnson & Greenbaum, 1980).

Some of the above-mentioned issues are in contention. For example, Sherman (1977) criticized some of the identified causes of sex-related differences, such as sex hormones and sex-linked, recessive gene transmission of intellectual ability. She indicated that there was no evidence to support these as factors contributing to sex-related differences.

When and Under What Circumstances Sex-Related Differences Become Manifest

For the most part, the sex-related differences in mathematics learning are not evident in the early elementary grades (Fennema, 1974a, 1977. 1978, 1980; Skypek, 1980; Stroud & Lindquist, 1942; Swafford, 1980), but become more pronounced in the upper elementary, junior high and senior high school years (Aiken, 1974, 1975; Armstrong, 1975. 1980; Callahan & Glennon, 1975; Fennema, 1974a; Fennema & Sherman, 1978; Fox, 1980;

Hilton & Berglund, 1974; Wolleat, Pedro, Becker, & Fennema, 1980).

When differences do manifest themselves in the middle grades, girls tend to outperform boys on low level cognitive tasks (e.g., computation), and boys tend to outperform girls on high level cognitive tasks (e.g., application and analysis) (Carry, 1970; Jarvis, 1964). However, in Jarvis' (1964) study, boys with IQs greater than 115 surpassed girls of comparable intelligence in all aspects of arithmetic achievement. Although Wozencraft (1963) found that, in general, third-grade girls were better in arithmetic than third-grade boys, differences were not as evident in her sixth-grade sample, nor within high and low ability groups.

The results of Fennema and Sherman's (1978) study conflict with the findings of the National Longitudinal Study of Mathematical Ability (NLSMA) (Carry, 1970), Jarvis (1964), and Wozencraft (1963). Fennema and Sherman tested sixth- and eighth-grade boys and girls ($N = 1320$), and concluded that:

> there are no universal sex-related differences in mathematics learning. Not only did females usually not perform better than males on computation (a low level cognitive task), but males usually did not perform better than females on the higher level cognitive tasks . . . (p. 197)

Although Jacobs' (1973) sample was much smaller ($N = 80$ seventh-graders), she also found no significant statistical differences between the sexes with respect to mathematics achievement in seventh grade.

The results of Fennema and Sherman's (1978) work supplemented and extended the findings of a study investigating sex-related differences in mathematics of female and male ninth- through twelfth-graders from the previous year (Fennema & Sherman, 1977). In general, sex-related differences with respect to cognitive variables were not found to be significant (with the exception of the results of two schools in which males outperformed females on spatial-visualization tasks). The researchers suggested that social class may be a contributing factor in sex-related differences (Fennema & Sherman, 1977). Women's changing role in society might also be contributing to the differences in achievement patterns resulting in many of the recent studies (Fennema & Sherman, 1978; Maccoby & Jacklin, 1974). As a result of these changing achievement patterns, it has been suggested that sex not be considered as a determining factor of individual differences, but instead, the teacher should be more concerned with the child's rate of learning, background experience, and general ability (Fennema, 1980b).

A few researchers criticized some of the early major research findings. For example, Fennema (1977, 1980a) and Schonberger (1978) criticized the NLSMA studies for inadequately reporting, analyzing, and interpreting the data. Another cause for concern was the lack of control for participation in mathematics (i.e., the number and type of mathematics courses taken). Armstrong (1980) claimed that the results of some studies (including the first NAEP) were confounded with participation in mathematics. The importance of including participation in mathematics as a variable when examining adolescent and adult sex-related differences was also stressed by Fennema (1977) and Fox (1977). It was concluded that sex-related differences become less pronounced when controlling for the number of years the subjects studied mathematics (Fennema & Sherman, 1978).

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Obviously taking heed of these results, Armstrong (1980) involved 13-year-olds and high school seniors in a study and found that the correlation between participation in mathematics and mathematics achievement was among the highest (out of seven independent variables analyzed with mathematics achievement). However, even though the number of mathematics courses was controlled for comparisons, the high school seniors' results still manifested sex-related differences (Armstrong, 1980).

Benbrow and Stanley's (1980) results would appear to support the finding that controlling for the number of years students studied mathematics did not eliminate sex-related differences (Armstrong, 1980; Maccoby & Jacklin, 1974; Schonberger, 1978). However, careful inspection of the results might indicate otherwise. They tested gifted seventh- and eighth-grade boys and girls and found males were superior to females in high cognitive mathematics tasks (including mathematical reasoning), but essentially no differences in verbal ability were identified ("Are Boys Better," 1980; Benbrow & Stanley, 1980; Kolata, 1980; "Why Are Boys," 1981). It has been recognized that at the time of early adolescence, there is greater variability among boys' general intelligence scores (Guilford, 1967). Since high IQ cases were used in the Benbrow and Stanley study, it might be expected that more boys' scores than girls' scores would be located in the extreme high percentage area of the frequency distribution. Therefore, it must be questioned whether these results confirmed the existence of sex-related differences with respect to boys outperforming girls in mathematics.

Effect of Sex-Biased Test Items and School-Related Tasks on Differences in Performance

It has been suggested that tests used to measure mathematics and reading achievement, as well as school-related assignments and tasks, are sex-biased (i.e., items and tasks are male- or female-oriented) causing sex-related differences. Janvier (1978) recognized that his graph on "Racing Cars" was sex-biased. The topic was more familiar to boys, and the tasks designed to accompany this graph proved to be more difficult for the high school girls. Leder (1974) presented boys and girls in the tenth grade (in Australia) with pairs of problems that contained stereotypically male and female situations. The subjects expressed preference for the problems that illustrated traditional sex roles. Male and female college students were the subjects in Graf and Riddell's (1972) study, designed to determine whether problem context, or the topic/situation of the problem affected success in solving it. It was found that the interaction between subjects' sex and problem context accounts for perceived problem difficulty, but it did not interfere with solving the problem.

Relationship Among Sex, Verbal, and Mathematical Ability

The correlation between verbal and mathematical ability was identified as early as 1912, by Edward L. Thorndike (Earp, 1969). More recently, in efforts to account for sex-related differences, Armstrong (1975) identified studies that confirmed Thorndike's observation. For example, Muscio (1962) found mathematical ability to be correlated with reading factors which included paragraph meaning, reading to understand precise directions, and reading to note details.

Despite the relationship that has been identified between language factors (Aiken, 1972), reading factors (Armstrong, 1975; Muscio, 1962), and mathematics-learning factors, sex-related differences have been reported. Fennema (1977, 1978), Fennema and Sherman (1976), and Fox (1977) questioned why females do not excel in mathematics since the verbal factor is such a salient component of mathematics and females tend to be superior to males in verbal ability. Fox (1977) offered the following reason:

> Perhaps the verbal factor related to mathematics is somewhat different from the verbal factor traditionally examined. In order to learn to use mathematics one must be facile with mathematical language. Language is vital to mathematics. Starting with numbers and numeration and continuing into the basic mathematical operations . . . mathematics has a highly specific symbolism and syntax which must be learned. As one progresses to higher mathematical levels, symbolism is increasingly used to express ideas. This symbolism is unique to mathematics; it is isolated within mathematics; and without a thorough knowledge of it, abstract mathematical thought is impossible. It would appear that while the verbal factor in mathematics might be very similar to the verbal factor in words, there are also differences. Conciseness is one difference. One mathematical symbol is equivalent to many words resulting in a high concept density in mathematics writing. Another difference is the learning of the symbols. Learners are embedded in a social milieu which constantly bombards them with words. Not so with mathematical symbols. Their use is restricted to a great degree to mathematics classes in schools. Whether or not such a specialized verbal factor can be identified is unknown, but it appears reasonable that such a factor exists and that it might provide some understanding of sex-related differences. (p. 101-102)

On the other hand, Fennema and Sherman (1976) criticized the reported relationship between verbal skills and sex as "an overgeneralization" (p. 8).

Armstrong (1975) suggested that when learning mathematics, females use their verbal ability (symbol-oriented development) and males rely upon analytical ability. As a result of approaching the learning of mathematics differently, Fennema (1975b) suggested that the development and reliance upon verbal ability might hinder the females' development of spatial ability (which is a requisite for high-level cognitive tasks in mathematics (Fennema, 1977)).

Investigating sex-related differences with respect to problem-solving, Meyer (1978) tested fourth-grade females and males. The data did not reveal achievement differences, suggesting that the intellectual strategies employed for problem-solving might be determined by sex. Also similar to the idea that males and females approach learning mathematics and mathematical problem-solving differently, Sheehan (1968) found "that sex is a difference that makes a difference in learning to solve algebra problems and that the sex differerce in problem-solving ability, transfer, and reasoning . . . do, in fact, affect school learning" (p. 86) for ninth-graders. On the other hand, Alexander (1962), who tested girls and boys in the seventh grade, did not find significant sex differences with respect to solving verbal arithmetic problems.

Sex-Related Differences with respect to Graph Comprehension

Studies examining sex-related differences with respect to comprehending the mathematical relationships expressed in graphs have been relatively few (Johnson, 1971; Strickland, 1938/1972; Vernon, 1950). Conforming with some of the literature on sex differences in adolescence (Maccoby, 1966b; Maccoby & Jacklin, 1974), Vernon (1950) found that on the average, boys' performance was superior to girls' performance involving the reading of charts, graphs, and tables, but no tests of significance were reported. However, Peterson and Schramm (1954) later reported that "There is nothing in the literature to indicate that sex makes a difference in the accuracy with which graphs are read" (p. 187). Strickland's (1938/1972) study supported this statement. There were no sex-related differences with respect to graph reading ability in grades one through four. In contrast, Johnson's (1971) fourth-, fifth-, and sixth-grade girls' mean scores on the graph reading pretest and posttest were superior to the boys' mean scores (no tests of significance were reported). However, many of her graph test items required simple arithmetical computation in which it has been found that elementary school girls excel (Carry, 1970; Jarvis, 1964).

To observe whether any sex-related differences exist with respect to graph reading ability, the results of fourth- and seventh-grade boys and girls were compared and analyzed in the present study. Seventh-graders were included in the study because if differences do occur, they become manifest at about the time of seventh grade, when children are about twelve or thirteen years old (Aiken, 1974; Armstrong, 1975;

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Fennema, 1974a, 1977; Maccoby, 1966b; Rappaport, 1978; Suydam & Riedesel, 1969).

Summary

Recent developments in cognitive psychology, in particular, schema theory, provide a framework for understanding comprehension of general discourse. Some researchers in mathematics education (Greeno, 1978; Silver, 1979, 1981) have applied some of the concepts of cognitive psychology in studies dealing with learning and comprehending mathematics. Specific kinds of mathematical relationships are expressed within a graphical framework. Analogous to general discourse, using graphs to communicate information might be dependent upon the reader's prior knowledge and the ability to bring that knowledge to bear. The abstract, symbolic notation employed in graphs to depict specific kinds of mathematical relationships might be more meaningful to readers who have a prior knowledge base.

Very few studies (Janvier, 1978; Price et al., 1974) have examined the role of cognitive factors in processing this mode of presenting information. Therefore, this research project has attempted to identify the effect of prior knowledge, specifically prior knowledge of topic, prior knowledge of mathematical content, and prior knowledge of graphical form on comprehending the mathematical relationships expressed in graphs. Whether sex was a contributing factor in graph comprehension, and how much of the variance of graph comprehension was attributed to prior knowledge independent of reading and mathematics achievement were also explored.

CHAPTER III

RESEARCH DESIGN AND METHOD

Instrumentation

Four assessment instruments were required for this study: a graph test measuring the comprehension of the mathematical relationships expressed in four different graphical forms; a prior knowledge inventory, measuring prior knowledge of topic, mathematical content, and graphical form (designed to reflect the prior knowledge assumed to be needed to comprehend the graph items); and reading and mathematics achievement tests.

Graph Test

As a result of a review of the literature, tests specially constructed to measure graph-reading ability were identified. Since these tests were not valid for the purpose of this study, it was determined that a graph test had to be constructed. Not only was it important to develop properly constructed graphs (Arkin & Colton, 1940; MacDonald-Ross, 1977) and to avoid excessive questioning that would stress low- or high-level cognitive tasks that might cause either sex to outperform the other (Carry, 1970; Jarvis, 1964), but it was also necessary to vary the topics of the graphs, the mathematical content in the graphs, and the graphical forms so that there would be some graphs containing aspects of prior knowledge that would be familiar to "average" fourth- and seventh-graders, and others that would be unfamiliar.

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The objectives (see Appendix A) were written after consulting New York City syllabi (Board of Education of the City of New York, 1962, 1979), a New York State Education Department bulletin (State Education Department, 1977), and NAEP booklets (NAEP, 1979a, 1979b). Suggestions for constructing graphs were also obtained from Arkin and Colton (1940), Eagle (1942), Goetsch (1936), and the Nuffield Foundation (1967).

Twelve graphs were constructed: three bar graphs, three circle graphs, three line graphs, and three pictographs. During the development of the test, six fourth-grade students were interviewed. Students were interviewed individually, although keeping with public school policy required children to leave classrooms in pairs. None of the children were confronted with the same graph. Each child was given two different types of graphs (one-at-a-time) to read (Janvier, 1978). Free response questions were asked, and responses were taped. From their responses, distractors for multiple-choice questions were written and questions were deleted or revised. As a result, each graph was accompanied by six multiple-choice items. The six items reflected the three tasks of comprehension. Two questions were "task a" items (requiring a literal reading of the data, title, or axes' labels); two questions were "task b" items (requiring comparisons and the use of mathematical concepts and skills to read "between the data"); and two questions were "task c" items (requiring an extension, prediction, or inference dependent upon prior knowledge to read "beyond the data"). The importance of arranging the items according to cognitive complexity was recognized at the time the six fourth-graders were confronted with the tasks. To avoid sex-biased items and possible influence of topic (Graf & Riddell, 1972;

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Janvier, 1978; Leder, 1974; Schonberger, 1978), six of the graphs were designed to be neutral ("The U.S. Government's 1981 Dollar Budget," "The Number of Calories in One Cup of Some Milk Products," "The Number of 200 Brooklyn Elementary Schools in which Electronic Calculators were used during 1960 through 1980," "Average Time of Sunset," "The Gross National Product during 1969 through 1979," and "First Grade Enrollment in One Brooklyn School District in 1962, 1968, 1974 and 1980") and some of the others were designed to avoid sex-stereotypes ("How Terry Spends a School Day," "Height of the Rodriguez Children in March, 1980," "The Number of Children in Mr. Kahn's Class Celebrating a Birthday during Each Month of the Year," "The Number of Books the Jones Children Read Per Month," and "Stamps Collected by Children").

Since a review of some of the schema theory literature suggested that comprehension varies with the amount of prior knowledge, four of the twelve graphs were designed to have topics that would be unfamiliar to the "average" fourth- and seventh-graders ("The U.S. Government's 1981 Dollar Budget," "The Number of Calories in One Cup of Some Milk Products," "The Gross National Product during 1969 through 1979," and "First Grade Enrollment in One Brooklyn School District in 1962, 1968, 1974 and 1980"). Eight of the graphs were designed with topics that were expected to be familiar to the "average" fourth- and seventh-graders ("How John Spends His Daily School Allowance," "How Terry Spends a School Day," "Height of the Rodriguez Children in March, 1980," "The Number of Children in Mr. Kahn's Class Celebrating a Birthday during Each Month of the Year," "The Number of 200 Brooklyn Elementary Schools in which

Electronic Calculators were used during 1960 through 1980," "Average Time of Sunset," "The Number of Books the Jones Children Read Per Month," and "Stamps Collected by Children"). Twice as many topics expected to be familiar to the "average" fourth- and seventh-graders were selected so as to avoid the possible effect of a failure situation in the event that prior knowledge of topic was determined to be a factor contributing to graph comprehension.

The amount of prior knowledge of mathematical content and graphical form was also taken into consideration in the design of the graphs and the questions that were constructed. It was expected that some of the mathematical concepts and skills would not be familiar to "average" fourth- and seventh-graders (e.g., percent). It was assumed from inpecting curriculum bulletins (Board of Education of the City of New York, 1962, 1979) that fourth-graders should have had some exposure to bar graphs, line graphs, and pictographs, and by seventh grade, students should have had some additional experience with circle graphs. To avoid having the order of the graphs influence students' performance (Carter, 1947), ten different randomly arranged orders of the graphs were presented to students. Table 1 describes the different arrangements of the Graph Test.

The score on the Graph Test (see Appendix A) can range from 0 to 72. The time needed for fourth- and seventh-graders to take this test was one hour.

Table 1

Form Arrangements of the Graph Test

	Form									
Graph	A	B	C	D	E	F	G	H	I	J
1	4	11	6	8	10	11	6	12	9	12
2	1	3	7	4	12	10	5	11	1	5
3	8	10	4	9	11	3	4	10	8	10
4	9	8	2	2	1	12	8	3	2	11
5	5	12	9	3	8	1	12	4	7	6
6	7	6	5	1	5	2	7	1	3	9
7	6	1	3	5	4	9	1	7	5	8
8	2	4	8	7	7	4	9	9	4	7
9	3	2	1	10	6	8	3	6	6	1
10	10	5	10	6	9	6	2	2	12	2
11	11	9	12	12	2	5	11	5	10	3
12	12	7	11	11	3	7	10	8	11	4
(p,r)[a]	(4,16)	(2,9)	(5,16)	(4,12)	(4,8)	(2,19)	(1,15)	(1,8)	(2,16)	(6,15)
Reverse Order[b]		X			X	X		X		X

Note. The table of random numbers from Guenther (1968) was used. One die was rolled to determine one of six possible pages (p). Four dice were rolled to determine a row (r) on that page.

[a](p,r) designates the page (p) and the row (r) determined by using dice. Reference is made to Guenther (1968).

[b]Since Graphs 11 and 12 were arranged last quite frequently, two dice were rolled five times to determine which form arrangements should be reversed. Therefore, B, E, F, H, and J were arranged in reverse order to avoid Graphs 10, 11, and 12 from always occurring near the end in the test booklet.

Validity of the Graph Test. Seven elementary/intermediate school teachers, each having more than five years of elementary/intermediate school teaching experience, were given the multiple-choice graph test to determine the validity of the test items. The teachers were presented with the definitions of the three tasks of comprehension ("task a," "task b," and "task c") and examples of each. To determine the face validity of the test items, they were asked to identify each of the 72 graph items as either "task a," "task b," or "task c." The six items accompanying each graph were arranged randomly to avoid the possible recognition of any pattern of arrangement. Agreement of at least four out of seven teachers per item determined whether the item had face validity. This would indicate that there is at most a .167 probability that agreement by four out of the seven teachers would occur by chance on any single item, using the Binomial Distribution Formula. Table 2 shows the number of teachers rating the tasks of the graph items in agreement with the intended task. Twenty-three (31.9%) of the items had to be rated a second time because at least four out of the seven teachers did not agree on the task level (see Table 3). The only item for which there was no agreement of four out of the seven teachers with its intended purpose was item 3 on Graph 7. However, this item was included as a "task b" item because, in accordance with the definition, it requires a comparison of the number of calculators used in 1960, 1970, and 1980, and it can be recognized that as the years progressed, the number of calculators used increased (which is visible by the direction of the line). Four of the teachers rated this as "task c" on the second rating.

Table 2

The Number[a] (*N*) of Teachers Rating the Tasks of Graph Items in Agreement with the Intended Task

Item	Graph 1		Graph 2		Graph 3		Graph 4		Graph 5		Graph 6	
	N	P(*N*)[b]	*N*	P(*N*)	*N*	P(*N*)	*N*	P(*N*)	*N*	P(*N*)	*N*	P(*N*)
Task a												
1	4	.167	7	.000[d]	6[c]	.001	5	.039	7	.000[d]	5	.039
2	7	.000[d]	7	.000[d]	7	.000[d]	7	.000[d]	7	.000[d]	7	.000[d]
Task b												
3	7	.000[d]	6[c]	.001	6	.001	6[c]	.001	4	.167	6[c]	.001
4	6	.001	6	.001	5[c]	.039	6	.001	4	.167	4	.167
Task c												
5	6[c]	.001	6[c]	.001	7	.000[d]	4[c]	.167	5	.039	6[c]	.001
6	6[c]	.001	5[c]	.039	4	.167	7	.000[d]	4[c]	.167	6	.001

[a]The Number (*N*) is out of 7.

[b]P(*N*) = The probability that at least *N* out of 7 teachers agree on the task of the item by chance.

[c]Items had to be rated a second time because there was no agreement (at least 4 out of 7 agreeing), the first time. Clarification and explanation preceded the second rating.

[d]$P(N) < .0005$.

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Table 2 (Continued)

The Number[a] (N) of Teachers Rating the Tasks of Graph Items in Agreement with the Intended Task

Item	Graph 7		Graph 8		Graph 9		Graph 10		Graph 11		Graph 12	
Task a	N	$P(N)$[b]	N	$P(N)$	N	$P(N)$	N	$P(N)$	N	$P(N)$	N	$P(N)$
1	6	.001	6	.001	7	.000[e]	5	.039	5	.039	6	.001
2	5	.039	6	.001	6	.001	5	.039	5	.039	5	.039
Task b												
3	d		7[c]	.000[e]	6[c]	.001	4	.167	6	.001	5[c]	.039
4	5	.039	7	.000[e]	4[c]	.167	7[c]	.000[e]	7	.000[e]	7[c]	.000[e]
Task c												
5	6	.001	7	.000[e]	6	.001	5[c]	.039	7[c]	.000[e]	6	.001
6	4	.167	7	.000[e]	7	.000[e]	7	.000[e]	5[c]	.039	7[c]	.000[e]

[a]The Number (N) is out of 7.

[b]$P(N)$ = The probability that at least N out of 7 teachers agree on the task of the item by chance.

[c]Items had to be rated a second time because there was no agreement (at least 4 out of 7 agreeing), the first time. Clarification and explanation preceded the second rating.

[d]No agreement (at least 4 out of 7 agreeing), was reached on the first nor second rating.

[e]$P(N) < .0005$.

Table 3

Number and Percentage of Graph Items Receiving Four or More Ratings in Agreement with the Intended Task

Number in Agreement	Number of Items			Percentage of Total
	First Rating	Second Rating	Total	(N out of 72)
7 (Unanimous)	18	5	23	31.9
6	14	9	23	31.9
5	10	5	15	20.8
4	7	3	10	13.9
Totals	59	22	71	98.5

Note. 23 (31.9%) of the items had to be rated a second time. Clarification and explanation preceded the rating. There was no agreement (at least 4 out of 7 agreeing) on one item (1.4%), Item number 3 on Graph 7.

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Since Royer and Cunningham (1978) indicated that teachers "are very good judges of whether topical material will be in the knowledge repertoire of students in their charge," (p. 38), the seven teachers were asked to identify the topics of the graphs that would be familiar and unfamiliar to the majority of fourth- and seventh-graders. There was unanimous agreement that four topics (one for each type of graph) would be unknown to the "average" fourth-grade student. This was in agreement with the four graphs designed bv the researcher to be unfamiliar (see pages 40-41). Five out of the seven teachers agreed that these four graph topics would also be unfamiliar to the "average" seventh-grade student.

Teachers also identified the vocabulary and mathematical concepts, or content, they thought students should know in order to comprehend the information presented in graphical form. This was helpful in constructing the Prior Knowledge Inventory.

Prior Knowledge Inventory

The Prior Knowledge Inventory (see Appendix B), consisting of three subtests (Topic, Mathematical Content, and Graphical Form) was designed following surveys compiled by Pearson, Cordon, and Hansen (Note 12), Pichert and Anderson (1976), and Weber (1979). However, due to the number of students tested and the wide scope of prior knowledge to be assessed, the free-response, open-ended style of these previous surveys was converted to a multiple-choice format. The scores on the subtests of the Prior Knowledge Inventory range from 0 to 52 on the Topic subtest, 0 to 64 on the Mathematical Content subtest, and 0 to 27 on the Graphical

Form subtest. To avoid having the order of the Prior Knowledge Inventory subtests influence students' performance, six different orders (the number of permutations of the three subtests) of the Prior Knowledge Inventory were arranged (Carter, 1947). The time needed for this test was one hour and fifteen minutes.

The topic, mathematical content, and graphical form of each of the twelve graphs was identified, and the seven teachers (previously mentioned) added or deleted information they thought was relevant or irrelevant. Open-ended, free-response items were constructed and then rewritten as multiple-choice items. The items were presented to six fourth-graders (different from the six used for the Graph Test interviews), who were encouraged to "think aloud" and make comments about the items under conditions similar to those for the Graph Test interviews. The students' comments were taped. From these responses the items were revised.

Graphical form items were constructed so that only knowledge of the structure of the four different graph-types was tested (Kosslyn, Note 13). Each graph-type was examined to identify the way the data are displayed, the framework used for representing the graph (e.g., circle, horizontal and vertical axes), and the type of relationship that can be recognized visually. The items designed were abstract exercises because the graphs used for this subtest were topic- and numerically content-free.

The Graph Test items and Prior Knowledge Inventory items were matched according to the prior knowledge assumed to be needed to respond correctly to the particular Graph Test items. See Appendix C for the Prior Knowledge Inventory items that are reflected in the Graph Test items.

Also, a key for matching the Graph Test items with the Prior Knowledge Inventory Items is available in Appendix C.

Pilot Study of the Tests

Prior to administering any tests (for the pilot study as well as the study), permission was obtained from the Office of Educational Evaluation, the Board of Education of the City of New York, and the Community District Superintendent (see Appendix D). Also, children participating in the pilot study and the study required parental consent (see Appendix D -- a similar letter was constructed, disseminated, and collected for the pilot study). Once all of the permission letters and forms were received, interviews were conducted (as described in the Graph Test and Prior Knowledge Inventory sections) and the Graph Test and Prior Knowledge Inventory were administered. The pilot tests were conducted during the Spring, 1980.

Graph Test results. Seventy-five fourth-graders were given the Graph Test, and KR-20 reliability of .89 was calculated. Sixty seventh-graders were given the Graph Test, and KR-20 reliability coefficient of .88 was calculated.

Prior Knowledge Inventory results. Sixty-seven fourth-graders were given the Prior Knowledge Inventory. A KR-20 reliability coefficient of .97 was calculated. The subtests, Topic, Mathematical Content, and Graphical Form had KR-20 reliabilities of .93, .97, and .93, respectively. Seventy-three seventh-graders were given the Prior Knowledge Inventory. A KR-20 reliability coefficient of .96 was calculated. The subtests, Topic, Mathematical Content, and Graphical Form had KR-20 reliabilities of .90, .95, and .86, respectively.

As previously mentioned, the validity of the Graph Test and Prior Knowledge Inventory was determined by receiving feedback from seven elementary and intermediate teachers who each had more than five years teaching experience in elementary and intermediate schools.

Reading and Mathematics Achievement Tests

Standardized achievement tests used in New York City (Joel, 1979) were reviewed (Buros, 1978). The Reading and Mathematics tests of the *SRA Achievement Series* (SRA) (Naslund, Thorpe, & Lefever, 1978) were determined to be the most appropriate standardized instruments for this study. Both Levels D and F (for beginning the fourth- and seventh-grades, respectively), have vocabulary and reading comprehension subtests for the Reading Test, and mathematics concepts and computation for the Mathematics Tests. (Level F also has a problem-solving subtest, not used in this study.) The score can range from 0 to 56 on Level D of the Reading Test, and from 0 to 90 on Level F. For the both levels of the Mathematics subtest, the score can range from 0 to 70. The reliability of the subtests ranges from .88 to .94 for Level D, and .83 to .96 for Level F. By inspecting the New York City curriculum guides (Board of Education of the City of New York, 1962, 1979), as well as the NAEP reports (1979a, 1979b), it can be shown that these subtests have content validity, and item difficulty is comparable to the same levels of other standardized tests used in New York City (Joel, 1979; Prescott, Balow, Hogan, & Farr, 1978; Tiegs & Clark, 1979).

Other criteria taken into consideration in selecting appropriate assessment instruments included the length of the test, clarity of

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directions for administration, and scoring format. For Levels D and F, only one hour was needed for the Reading Test, and 65 minutes were needed for Level D and 90 minutes for Level F of the Mathematics Test. The amount of testing time was not overburdening for fourth- and seventh-graders. The directions for administering the tests were very clear and adequately detailed instructions were available in the manual. Very little special preparation was required to administer each test. This was a concern because proctors were used to administer the tests. Level D had a hand-scorable format where answers were marked in the test booklet. This was a concern because fourth-graders have had very little experience, if any, transferring answers from a test booklet to a separate answer sheet. Level F material included a test booklet and a separate answer sheet.

There was no "Graph" subtest on the Mathematics Test nor were there any graph items throughout the test for both levels. This was a desirable feature because the presence of graph items on the Mathematics Test might have caused a superficially high correlation between the independent variable, mathematics achievement, and the dependent variable, graph comprehension.

The 1978 Edition of the SRA was not available at the time that the Association of Teachers of Mathematics of New York City (ATMNYC) Task Force reviewed the standardized mathematics tests used in New York City (Joel, 1979). Also, this edition was not reviewed in the *Eighth Mental Measurements Yearbook* (Buros, 1978). However, geometry, measurement, metrics, and practical application topics, scarcely found in the 1971

Edition (Joel, 1979), are sufficiently represented in the 1978 Edition (Naslund et al., 1978).

The Sample

Fourth-graders were selected because it is by the fourth grade that most of the preliminary, elementary work with graphs should have been accomplished (Board of Education of the City of New York, 1962; NAEP, 1979b), they should have "reached a minimally acceptable level of adult graphicacy" (Wainer, Note 10, p. 11), and, by the fourth grade, children should have achieved a sufficient command of reading and arithmetic skills needed for testing graph reading skills (Strickland, 1938/1972). Seventh-graders were selected because it is during the seventh grade that sex-related differences tend to become manifest (Armstrong, 1975; Fennema, 1974a, 1977, 1978; Maccoby, 1966b; Suydam & Riedesel, 1969). Also, it is by the seventh grade that most of the instruction dealing with graphs should have been accomplished (Board of Education of the City of New York, 1979; Hogan et al., 1978), and that seventh-graders should have had more experience with bar graphs, line graphs, pictographs, and circle graphs. These experiences should account for more prior knowledge of graphical form, as well as more prior knowledge of topics and mathematical content.

The sample was chosen from one of the 32 New York City School Districts. There were four elementary schools, two junior high schools, and one K-8 school. The schools are located in stable (there is no constant influx or exodus of families from these communities) middle-class communities, but some children are bused from poor, disadvantaged communities. The study was designed so that the sample would be composed of at least four hundred children (100 fourth- and seventh-grade boys and girls). Information regarding sex and native-English-speaking status was collected by having students check appropriate spaces on the cover sheet of the Prior Knowledge Inventory. Native-English-speaking students were selected to avoid any influence of foreign language background.

It was found that an unexpectedly large number of students were not native-English-speakers (41.7% of the fourth-graders, and 44% of the seventh-graders). A very large percentage of the minority students was not native-English-speaking (89.1% of the fourth-grade minorities, and 84.4% of the seventh-grade minorities). As a result, the racial status variable was deleted from the study because native-English-speaking minorities were inadequately represented. The analysis and breakdown of the sample by sex and minority/non-minority status is presented in Tables 4 and 5.

Thus, the sample consisted of 101 fourth-grade boys, 103 fourth-grade girls, 102 seventh-grade boys, and 83 seventh-grade girls. Students who participated in the pilot study (Spring, 1980), and who were held over (i.e., were repeating the fourth- or seventh-grade in the Fall, 1980), were deleted from the sample.

Despite having a few less subjects in the sample than originally expected, the fourth- and seventh-grade sample size still yield high statistical power greater than .94 for medium size effect ($\alpha = .01$) (Cohen, 1977, p. 91), and the sample size was consistent with the suggestions of Kerlinger and Pedhazur (1973) for the sample size needed

Table 4

Analysis of Fourth-Grade Sample from 5 Brooklyn Public Schools

Subjects	Total Grade Enrollment	Total No. of Minorities	% of Minorities	No. who had Permission to Participate (No. Tested)	% with Permission to Participate	No. of Native-English-Speakers with Permission to Participate	% of Native-English-Speakers with Permission
Boys	205	48	23	205	100.0	122	59.5
Girls	235	40	17	234	99.6	134	57.2
Total	440	88	20	439	99.7	256	58.3

Subjects	No. of Native-English-Speaking Minorities	% of Native-English-Speakers who are Minority	No. of Complete Sets of Data of Native-English-Speakers	No. of Native-English-Speaking Minorities with Complete Sets of Data	% of Complete Sets of Data that Belong to Minorities	% of Native-English-Speakers for Whom There are Complete Sets of Data
Boys	16	13.1	101	15	14.9	82.3
Girls	12	9.0	103	8	7.7	76.9
Total	28	10.9	204	23	11.3	79.7

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Table 5

Analysis of Seventh-Grade Sample
from 3 Brooklyn Public Schools

Subjects	Total Grade Enrollment	Total No. of Minorities	% of Minorities	No. who had Permission to Participate (No. Tested)	% with Permission to Participate	No. of Native-English-Speakers with Permission to Participate	% of Native-English-Speakers with Permission
Boys	240	56	23.5	240	100.0	144	60.0
Girls	221	49	22.0	219	99.1	113	51.6
Total	461	105	22.8	459	99.6	257	56.0

Subjects	No. of Native-English-Speaking Minorities	% of Native-English-Speakers who are Minority	No. of Complete Sets of Data of Native-English-Speakers	No. of Native-English-Speaking Minorities with Complete Sets of Data	% of Complete Sets of Data that Belong to Minorities	% of Native English-Speakers for Whom There are Complete Sets of Data
Boys	21	14.6	102	13	12.7	70.8
Girls	19	16.8	83	13	15.7	73.5
Total	40	15.6	185	26	14.1	72.0

for a multiple regression analysis. The sample size also allows for minimal shrinkage of multiple R (Kerlinger & Pedhazur, 1973).

Procedure and Data Collection

In May, 1980, the researcher was invited to be a guest speaker at a Principals' Conference at the District Office. At this time, the principals were informed of the objectives of the research project, and tentative testing dates. Also, they were told that Title I schools (schools that receive money from the Federal Government to implement special programs for minority/disadvantaged students) were not going to be included in the study to avoid possible external effects of supplemental programs. Seven principals volunteered to allow their students to participate in the study. They were from four elementary schools, two junior high schools, and one K-8 school.

In early September, 1980, testing schedules were discussed with the seven principals. The researcher also visited each of the 29 classes to explain the research project to the children and distribute the permission letters. Prior to beginning the testing, all permission letters were returned and rosters were prepared and typed. The testing was conducted in October, November, and the first week of December, 1980.

Nineteen proctors were recruited from the Teacher Training Program at Saint Francis College. Each proctor had successfully completed a course in Tests and Measurements and had demonstrated competence in administering and proctoring standardized tests. To insure uniform testing conditions (Tuinman, 1973-1974), orientation sessions were held for the proctors to review the expected time of arrival at each testing session; expected preparation procedures; expected proper attire; proctoring assignments; tests, and test administration instructions. Each proctor received copies of the four tests, answer keys, directions for administering the tests, and maps of the location of the assigned schools. Similar to Fennema and Sherman (1977), the proctors were assigned according to their availability. For the most part, each proctor was responsible for the same class for each of the four testing sessions. In addition, twenty-nine teacher-training students, also from Saint Francis College, were enlisted to hand-score the papers. Each paper was checked by the researcher to assure accuracy of the ratings and recording of scores.

Each of the four tests was administered during four different testing sessions. The Prior Knowledge Inventory was administered first to determine the amount of prior knowledge of topic, mathematical content, and graphical form the students had prior to confronting the Graph Test. To avoid having any of the content of the Prior Knowledge Inventory fresh in the minds of the students when taking the Graph Test, at least four weeks lapsed before administering the Graph Test, and within this time the SRA Reading Test and the SRA Mathematics Test were given.

Analysis of Data

The research questions were investigated by correlational and multiple regression analyses for the fourth- and seventh-graders separately. To avoid having the results confounded with other cognitive components (Consulting Statisticians, Inc., Note 11; Kosslyn, Note 14), and in efforts to be as precise as possible in analyzing the data collected, second-order partial correlations, partialing out mathematics achievement and reading achievement, were computed to determine the unique contribution of prior knowledge of topic, mathematical content, and graphical form to graph comprehension. First-order partial correlations, partialing out reading achievement from mathematics achievement, and partialing out mathematics achievement from reading achievement, were computed to determine the unique contribution of reading and mathematics achievement to the variance of graph comprehension. Sex, mathematics achievement, and reading achievement were controlled in the regression analysis to determine whether prior knowledge contributed to the prediction of graph comprehension independent of any of these previously entered measures, information about which is readily available in the public school setting.

CHAPTER IV

RESULTS

Prior to considering the research questions, the frequency distributions and percentages of students taking the six different arrangements of the Prior Knowledge Inventory and the ten different arrangements of the Graph Test were inspected. Even though a near-equal representation of each test arrangement was distributed during each testing session, these distributions were inspected to determine whether there was a near-equal representation of each test arrangement among the complete sets of data. This was a concern because many sets of data were not included in the final analysis due to missing cases (see The Sample, Chapter III, p. 52). The near-equal frequency distributions and percentages of the different forms of the Prior Knowledge Inventory and the Graph Test for students who made up the sample for this study are reported in Table 6.

Even though a pilot study was conducted, KR-20 reliability coefficients were also calculated for the fourth- and seventh-grade sample of the study to establish the internal consistency of the instruments designed by the researcher. Similar to the high reliability coefficients of the researcher-designed tests administered to the pilot groups, high KR-20 reliability coefficients were also calculated for each researcher-designed test administered during the study (see Table 7).

After inspecting the frequency distributions of the different arrangements of the tests and the reliability coefficients for each researcher-designed instrument, the zero-order correlations between in-

Table 6

Frequency Distributions and Percentages of Students[a] Taking Different Forms of the Prior Knowledge Inventory and Graph Test

		Prior Knowledge Inventory Form						
		A	B	C	D	E	F	Total
Fourth Graders	N[b]	37	37	30	33	33	34	204
	%	18	18	15	16	16	17	
Seventh Graders	N	30	35	35	29	26	30	185
	%	16	19	19	16	14	16	

		Graph Test Form										
		A	B	C	D	E	F	G	H	I	J	Total
Fourth Graders	N	23	22	17	26	16	17	23	23	17	20	204
	%	11	11	8	13	8	8	11	11	8	10	
Seventh Graders	N	21	12	21	18	19	19	18	16	22	19	185
	%	11	6	11	10	10	10	10	9	12	10	

[a] Frequency Distributions and Percentages of Students for whom complete sets of data were available.

[b] N = Number of students.

Table 7

Reliability of Researcher-Designed Tests
Administered During Fall, 1980

Test	Grade	No. of Items	No. of Native-English-Speaking Subjects	KR-20 Reliability
Graph	4	72	232	.89
	7	72	215	.91
Prior Knowledge Inventory	4	143	261	.96
	7	143	245	.91
Topic Subtest	4	52	261	.92
	7	52	245	.82
Mathematical Content Subtest	4	64	261	.95
	7	64	245	.86
Graphical Form Subtest	4	27	261	.90
	7	27	245	.81

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dependent measures were examined. Most of the fourth- and seventh-grade zero-order correlations yielded similar patterns. In particular, prior knowledge of topic and prior knowledge of graphical form had the highest positive correlation with reading achievement for both fourth- and seventh-graders. Also, in both cases, prior knowledge of mathematical content had the highest positive correlation with mathematics achievement. For fourth-graders, mathematics achievement had the highest positive correlation with reading achievement and prior knowledge of graphical form, and for seventh-graders, mathematics achievement had the highest positive correlation with prior knowledge of mathematical content. In all cases, sex was least correlated with every measure. The zero-order correlations for all continuous measures were significant at $p < .001$. The zero-order correlations between sex and reading achievement, mathematics achievement, and the dependent measure, graph comprehension, were very low, but significant ($p < .05$) for only the seventh-graders (see Table 8). The zero-order correlations of fourth- and seventh-grade results for boys and girls separately, are reported in Appendix E.

The first six questions posed were examined using zero-, first-, and second-order partial correlations. Second-order partial correlations, partialing out mathematics achievement and reading achievement, were computed to determine the unique contribution of prior knowledge of topic, mathematical content, and graphical form to graph comprehension. First-order partial correlations, partialing out reading achievement from mathematics achievement, and partialing out mathematics achievement from reading achievement, were computed to determine the unique contribution of

Table 8

Zero-Order Partial Correlation Matrix for
Fourth Grade (N = 204) and Seventh Grade (N = 185)

Variables	Sex	Topic	Mathematical Content	Graphical Form	Reading Achievement	Mathematics Achievement	Graph Comprehension
Sex[a]		.00	.09	.00	.10	.09	.02
Topic	*.11*		.37**	.53**	.65**	.55**	.63**
Mathematical Content	*.06*	*.54***		.48**	.43**	.52**	.61**
Graphical Form	*.01*	*.45***	*.39***		.60**	.58**	.62**
Reading Achievement	*.16**	*.70***	*.50***	*.47***		.58**	.70**
Mathematics Achievement	*.23**	*.46***	*.62***	*.40***	*.58***		.67**
Graph Comprehension	*.15**	*.57***	*.65***	*.44***	*.69***	*.69***	

Note. The entries above the diagonal are the correlations for the fourth grade. The italicized entries below the diagonal are the correlations for the seventh grade.

*p < .05.

**p < .001.

[a]Males =0, Females =1.

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mathematics and reading achievement to graph comprehension, respectively. To determine the significance of the difference between fourth- and seventh-grade males' and females' performance on each measure, t-test results were also computed, analyzed, and reported.

Questions Explored

1. Is prior knowledge of topic related to comprehending the mathematical relationships expressed in graphs?

The second-order partial correlation between the Topic subtest of the Prior Knowledge Inventory and the criterion variable measured by the Graph Test, with reading and mathematics achievement partialed out, was .23 ($p < .01$) for fourth-graders and .15 ($p < .05$) for seventh-graders. Although the correlations were low, they were both significant (see Table 9).

2. Is prior knowledge of mathematical content related to comprehending the mathematical relationships expressed in graphs?

The second-order partial correlation between the Mathematical Content subtest of the Prior Knowledge Inventory and the criterion variable measured by the Graph Test, with reading and mathematics achievement partialed out, was .38 for fourth-graders and .34 for seventh-graders. Both correlations were significant ($p < .01$) (see Table 9).

3. Is prior knowledge of graphical form related to comprehending the mathematical relationships expressed in graphs?

The second-order partial correlation between the Graphical Form subtest of the Prior Knowledge Inventory and the criterion variable measured by the Graph Test, with reading and mathematics achievement

Table 9

Second-Order Partial Correlation Matrix for
Fourth Grade (N = 204) and Seventh Grade (N = 185)
Controlling for Reading Achievement and Mathematics Achievement

Variables	Topic	Mathematical Content	Graphical Form	Graph Comprehension
Topic		.03	.15*	.23**
Mathematical Content	.31**		.21**	.38**
Graphical Form	.18*	.14		.24**
Graph Comprehension	.15*	.34**	.11	

Note. The entries above the diagonal are the second-order partial correlations for the fourth grade. Entries below the diagonal are the second-order partial correlations for the seventh grade.

*$p < .05$.

**$p < .01$.

partialed out, was .24 ($p < .01$) for fourth-graders and .11 for seventh-graders. Only the second-order partial correlation for the fourth-graders, although low, was significant (see Table 9).

4. Is reading achievement related to comprehending the mathematical relationships expressed in graphs?

The first-order partial correlation between reading achievement, measured by the SRA Reading Test, and the criterion variable, measured by the Graph Test, with mathematics achievement partialed out, was .51 for fourth-graders and .48 for seventh-graders. Both correlations were significant ($p < .001$) (see Table 10).

5. Is mathematics achievement related to comprehending the mathematical relationships expressed in graphs?

The first-order partial correlation between mathematics achievement, measured by the SRA Mathematics Test, and the criterion variable, measured by the Graph Test, with reading achievement partialed out, was .46 for fourth-graders and .49 for seventh-graders. Both correlations were significant ($p < .001$) (see Table 10).

6. Is sex related to comprehending the mathematical relationships expressed in graphs?

The zero-order correlation between sex and the criterion variable measured by the Graph Test, was found to be .02 for fourth-graders and .15 for seventh-graders. Although the correlation for seventh-graders was very low, it was significant ($p < .05$) (see Table 8).

Table 10

First-Order Partial Correlations of
Fourth- and Seventh-Grade Graph Comprehension Results
with Reading and Mathematics Achievement
Controlling for Mathematics and Reading Achievement, Respectively

	Graph Comprehension		
Variable	Fourth-Grade	Seventh-Grade	Control Variable
Reading Achievement	.51*	.48*	Mathematics Achievement
Mathematics Achievement	.46*	.49*	Reading Achievement

*$p < .001$.

To determine the significance of the difference between the mean scores for fourth- and seventh-grade males and females with respect to the independent measures, as well as the dependent measure, multiple *t*-tests were computed. To avoid compounding the probability of a Type I error in computing multiple *t*-tests on the same set of data, the level of significance was set at .01 (for a two-tailed test), calculated by using the formula, $p = 1 - (1 - \alpha)^K$, where $p = .05$, and K = 6 (Hays, 1973, p. 611). None of the differences between the mean scores for fourth-grade males and females was significant (see Table 11). Only the difference between the mean scores for seventh-grade males and females for mathematics achievement was significant in favor of females (see Table 12).

Zero-, first-, and second-order partial correlations, discussed for total fourth- and seventh-grade cases in Questions 1 through 5, were also examined for boys and girls separately. These are reported in Appendix E.

7. What is the optimal linear combination of the independent variables in terms of predicting comprehension of mathematical relationships expressed in graphs?

A hierarchical multiple regression procedure was used to explore this question. Since studies have identified a correlation between arithmetic and reading achievement and graph reading ability (Goetsch, 1936; Herrmann, 1976; Johnson, 1971), it was questioned whether prior knowledge of topic, mathematical content, and graphical form of the graphs significantly contribute independently of mathematics and reading achievement to the prediction of graph comprehension. Children's mathematics and reading achievement scores are readily available in the public

Table 11

Means, Standard Deviations, and t-Values for All Variables for Fourth Grade

Variables	Boys (n=101)		Girls (n=103)			All Cases (n=204)	
	M	*SD*	*M*	*SD*	*t*	*M*	*SD*
Topic	27.76	10.34	27.84	10.37	.05	27.80	10.33
Mathematical Content	33.39	15.44	35.95	12.38	1.31	34.68	14.00
Graphical Form	16.14	6.55	16.15	5.37	.01	16.14	5.97
Reading Achievement	39.67	9.70	41.53	9.15	1.41	40.61	9.45
Mathematics Achievement	46.20	13.99	48.49	12.79	1.24	47.35	13.18
Graph Comprehension	30.49	11.65	30.97	10.52	.31	30.73	11.07

Note. df = 202.

Table 12

Means, Standard Deviations, and *t*-Values for All Variables for Seventh Grade

Variables	Boys (*n*=102)		Girls (*n*=83)			All Cases (*n*=185)	
	M	*SD*	*M*	*SD*	*t*	*M*	*SD*
Topic	38.86	6.38	40.07	4.22	1.48	39.41	5.54
Mathematical Content	51.08	6.67	51.84	5.85	.82	51.42	6.31
Graphical Form	21.89	3.25	21.93	3.77	.07	21.91	3.48
Reading Achievement	51.53	15.17	56.11	13.68	2.13	53.58	14.66
Mathematics Achievement	31.63	11.84	37.12	10.94	3.25*	34.09	1[illegible].74
Graph Comprehension	39.86	11.75	43.24	10.46	2.04	41.38	11.28

Note. *df* = 183.

*$p < .01$.

school setting. Whether prior knowledge should be assessed prior to presenting a unit on graph reading to children, can be determined by analyzing the unique contribution of prior knowledge by controlling for mathematics and reading achievement. Also, this procedure is consistent with the correlation analyses for Questions 1 through 3.

There is insufficient research available to support an order of entry for the three aspects of prior knowledge. Therefore, prior knowledge of topic, mathematical content, and graphical form were entered last as a set in the regression equation.

The fourth- and seventh-grade results were analyzed for boys and girls separately. Since the differences in regression slopes were negligible, only the results of the fourth- and seventh-grade total cases are reported and discussed.

Tables 13 and 14 illustrate the regression analysis for each step of inclusion for fourth- and seventh-grade, respectively. In the fourth-grade analysis, sex entered first into the equation was not significant. It can be observed in Table 13 that sex accounts for virtually no portion of the variance of graph comprehension. On the other hand, sex entered first into the seventh-grade equation contributed very little to the variance of graph comprehension (only 2%), but this contribution was significant ($p < .05$) (see Table 14). The meaningfulness of such a small contribution to the variance of graph comprehension is questioned.

Since the variables were entered cumulatively, the significance test for the change in multiple R^2 (ΔR^2) was calculated. For both fourth- and seventh-graders, mathematics and reading achievement accounted for

Table 13

Fourth-Grade Total Cases
Hierarchical Regression Analysis for Graph Comprehension

Equation	Variable(s) Entered	R^2	R	F	ΔR^2	F
1	Sex [a]	.000	.022	.10		
2	Mathematics Achievement Reading Achievement	.598	.773	99.15*	.598	148.76*
3	Topic Mathematical Content Graphical Form	.681	.825	70.13*	.083	17.09*

Note. $n = 204$.

*$p < .01$.

[a] Males = 0, Females = 1.

Table 14

Seventh-Grade Total Cases
Hierarchical Regression Analysis for Graph Comprehension

Equation	Variable(s) Entered	R^2	R	F	ΔR^2	F
1	Sex [a]	.022	.149	4.17*		
2	Mathematics Achievement Reading Achievement	.600	.774	90.31**	.578	130.77*
3	Topic Mathematics Content Graphical Form	.647	.804	54.36**	.047	7.90**

Note. $n = 135$.

*$p < .05$.

**$p < .01$.

[a] Males = 0, Females = 1.

a significant portion of the variance of graph comprehension ($p < .01$) (see Tables 13 and 14). Entering prior knowledge of topic, mathematical content, and graphical form as a set last in the equation also contributed a significant portion of the variance of graph comprehension ($p < .01$) (see Tables 13 and 14). Therefore, prior knowledge is a predictor, over and above that of mathematics and reading achievement.

The optimal linear combination for the fourth-grade regression equation included all of the variables except sex. Sex was not a unique contributing factor in fourth-graders' ability to comprehend the mathematical relationships expressed in graphs, i.e., sex did not predict fourth-graders' success in graph comprehension (see Table 15).

The optimal linear combination for the seventh-grade regression equation included only mathematics achievement, reading achievement, and prior knowledge of the mathematical content employed in the graphs. Sex, prior knowledge of topic, and prior knowledge of graphical form were not unique contributing factors in the seventh-graders' ability to comprehend the mathematical relationships expressed in graphs (see Table 16).

Table 15

Fourth-Grade Total Cases
Variables in the Regression on Graph Comprehension Equation

Variable	Beta	F
Sex [a]	- .05	1.49
Mathematics Achievement	.21	14.13**
Reading Achievement	.29	23.76**
Topic	.06	9.25**
Mathematical Content	.26	28.53**
Graphical Form	.10	3.98*

Note. df = 1/197.

*$p < .05$.

**$p < .01$.

[a]Males = 0, Females = 1.

Table 16

Seventh-Grade Total Cases
Variables in the Regression on Graph Comprehension Equation

Variables	Beta	F
Sex [a]	.01	.03
Mathematics Achievement	.30	21.67*
Reading Achievement	.33	23.32*
Topic	.04	.30
Mathematical Content	.26	17.95*
Graphical Form	.05	.78

Note. df = 1/178.

*$p < .01$.

[a]Males = 0, Females = 1.

CHAPTER V

DISCUSSION AND CONCLUSION

The present study examined the effect of prior knowledge on the ability to comprehend the mathematical relationships expressed in graphs by using a schema-theoretic framework. Reading achievement, mathematics achievement, and sex were also examined to determine whether the contribution of prior knowledge to the prediction of variance in graph comprehension was independent of these other independent variables.

The results of this study must be interpreted with caution because the sample was not random. However, although the findings are limited, generalizations can be made to a similar urban, native-English-speaking fourth- and seventh-grade public school population, confronted with similar tasks designed for this study, under similar conditions.

Schema Theory Extended to Graph Comprehension

In an effort to examine the global features of prior knowledge with respect to graph comprehension, three aspects of prior knowledge were identified -- prior knowledge of topic, prior knowledge of mathematical content, and prior knowledge of graphical form. The saliency of these different aspects of prior knowledge with respect to graph comprehension seems to be affected by developmental differences; i.e., younger children's ability to comprehend graphs seems to be more dependent upon certain aspects of prior knowledge than that of older children. In any case, the results of this study suggest that the schema-theoretic perspective for understanding the comprehension of general discourse should be extended to include graph comprehension.

One possible way of interpreting the results of this study is to make an analogy between graph comprehension and general discourse comprehension by using Noam Chomsky's terms, "deep structure," and "surface structure" (Smith-Burke, Note 9). It is possible that cues for retrieving information about the topic of the graph and the graphical form of the graph come from the "surface structure" of the graph, which might include the title, axes' labels, and the graphic configuration (e.g., horizontal and vertical axes, or a circle). These two aspects of prior knowledge might be utilized more easily in comprehension than that of mathematical content, for which there seems to be a more complex, "deep structure." The mathematical relationships depicted by a graphic display might not be as obvious for children to identify, especially if they are unfamiliar with the mathematical content employed in the graph, or they are not adept at interpreting the symbolic notation that can act as a cue for retrieving relevant background knowledge to aid in comprehension.

Prior Knowledge of Topic

Having prior knowledge of the topic of the graph seems to be more important for fourth-graders than for seventh-graders when attempting to comprehend the message within graphs. This is indicated by the fourth- and seventh-grade regression equations. Prior knowledge of topic uniquely contributed to the prediction of graph comprehension for fourth-graders, but not for seventh-graders. This suggests that fourth-graders, in general, have a more restricted general or global knowledge base, and need as much pertinent information about the new task being confronted as possible. It may also be the case that fourth-graders cannot treat the mathematical content abstractly or independently, and must relate it to concrete terms, such as the topic of the graph; i.e., for fourth-graders, mathematical content might be tied to given topics which might inhibit their comprehension of the message in the graph.

As students grow older, their general background knowledge base increases and perhaps students do not focus as much attention and/or concern on the topic of the graph. Also, by seventh-grade, students may have become more adept at abstract thinking. They can perhaps more effectively employ default procedures or retrieve related information in long-term memory by using the surface structure cues so as to fill in the "gaps" in their schemata relating to the topics of the graphs.

Implications. Communicating in graphical form might be too abstract for young children. The topic of the graph might be the only means by which young children can relate this abstract structure to something concrete and hence, be meaningful to them. Since the topic of the graph can be thought of as part of the surface structure of the graph which is easily recognized, it is suggested that teachers prepare young children for tasks that involve graph reading by helping them to build their prior knowledge for the topic of the graph. Pre-graph reading sessions involving concrete and/or semi-concrete activities might help children build necessary topic schemata that might make the graph more meaningful to them. This can be done by using representational models or pictures, allowing children to explain what they know about the topic, and/or planning field trips related to the topic of the graph. Such pre-graph reading activities were designed by Strickland (1938/1972).

Prior Knowledge of Mathematical Content

Inspection of the second-order partial correlations and the fourth- and seventh-grade regression equations seems to indicate that prior knowledge of the mathematical content employed in the graphs is the most salient contributor to graph comprehension out of the three aspects of prior knowledge. As previously mentioned, the mathematical content is implicit in the graph, represented as a deep-structure. Fourth- and seventh-graders' lack of familiarity with the underlying mathematical concepts used as part of the deep structure of the graph, or their inability to recognize cues to help retrieve relevant information, seems to impede graph comprehension. This interpretation highlights Thomas' (1933) and Vernon's (1952) observations. Students who are unable to understand concepts and perform fundamental operations when isolated from the graph and explicitly stated, would be limited in comprehending the message in the graph which is depicted by these implicitly stated mathematical relationships.

Implications. As a result of the apparent importance of prior knowledge of mathematical content with respect to graph comprehension, there are two suggested activities that teachers might consider to incorporate in their lessons on graph reading. The first is that children, fourth-graders as well as seventh-graders, should be actively involved in collecting "real-world" data to construct their own simple graphs. Children should be encouraged to verbalize the relationships and patterns observed among collected data (e.g., larger than, twice as big as, continuously increasing). In this way, the application of mathematics to the "real-world" might enhance students' concept development and build and expand relevant mathematics schemata needed to comprehend the implicit mathematical relationships expressed in graphs. Graph activities similar to the ones suggested, but more advanced, were used with high school students in Janvier's (1978) study.

The second suggestion is to teach or review the relevant mathematical concepts needed to interpret selected graphs prior to distributing the graph activities to the children. This pre-graph reading activity might help children recognize the mathematical concepts in the deep structure of the graph and/or enhance the retrieval of the relevant prior knowledge that might make the message in the graph more meaningful.

Prior Knowledge of Graphical Form

Having prior knowledge of the form of the graph seems to be more important for fourth-graders than for seventh-graders. This is indicated by the fourth- and seventh-grade regression equations. Prior knowledge of graphical form uniquely contributed to the prediction of graph comprehension for fourth-graders but not for seventh-graders. This suggests that fourth-graders, in general, might have a more restricted knowledge base with respect to the configuration of graphs and they might need as much specific information relevant to the new task as possible. Also, similar to Bestgen's (1980) and Janvier's (1978) observations, young children might not be adept at scanning the graph to locate important features of the graphical form (e.g., the key in a pictograph).

By seventh grade, it is expected that students have had more meaningful encounters with a variety of graph-types, enabling them to scan the surface structure more effectively. Also, students at this age might have become more adept at abstract thinking. Therefore, students might not be confined to the concrete dimensions of the configuration of the graph. They might also be more adept at relating the prior knowledge they have stored regarding one graph-type to an unfamiliar type more easily than fourth-graders. Also, similar to their facility with prior knowledge of topic, seventh-graders can perhaps more effectively employ default procedures or retrieve related information in long-term memory by using the surface structure cues so as to fill in the "gaps" in their schemata relating to the form of the graphs.

Implications. The symbolic notation and configuration characteristic of graphs might be too abstract for young children. The surface structure depicted by the form of the graph might distract children from the essence of the message. Therefore, two activities that teachers might consider to incorporate in their lessons on graph reading are suggested. One activity might use the same graph-type for two different but appropriate situations. Children should be encouraged to observe and discuss the similar features (graphical form) of both graphs. The differences (including the topic and perhaps the mathematical content) should also be discussed. In another activity, children could be exposed to other appropriate graph-types that can be used to express the same data, only the visual display would be different, but the essence of the message would be the same (e.g., bar graph and pictograph types can be compared for similarities and differences). Children should also be encouraged to discuss their observations with respect to the two different graph-types. These activities might help children to build relevant graphical form schemata so that they do not become distracted by the surface structure which might prevent them from extracting the message of the graph.

Reading and Mathematics Achievement, Prior Knowledge, and Graph Comprehension

Achievement and Prior Knowledge

With respect to the zero-order correlations, prior knowledge of topic and prior knowledge of graphical form were most highly correlated with reading achievement. The Topic subtest of the Prior Knowledge Inventory contained many vocabulary items, which may be the component that could have contributed to the high correlation. The Graphical Form subtest, however, was constructed to be topic- and numerically content-free. Such a high correlation between graphical form and reading achievement supports Fox's (1977) contention with respect to verbal factors and mathematics in general; that is, that there might be a specialized verbal factor underlying the language of graphs. The symbols and syntax used in graphic displays are unique and limited to such forms of communication.

As expected, prior knowledge of mathematical content was most highly correlated with mathematics achievement (with respect to the zero-order correlations). However, knowledge about the mathematical content particular to the graph being read contributed to comprehending the message in the graph independent of mathematics achievement for both fourth- and seventh-graders.

Implications. The different aspects of prior knowledge seem to be positively correlated with the two global predictors of success in school-related tasks, reading and mathematics achievement. Therefore, teachers should design activities that help children build and expand relevant schemata by providing them with opportunities to verbalize any abstract concepts, especially those related to mathematics in general.

Many abstract concepts are communicated via graphic displays. The graphic representation is equivalent to many words. The concept density is very high which implies the need for a rich prior knowledge base. As previously mentioned, teachers should encourage children to describe, explain, and discuss what they "see" in graphs. This might assist the students in refining necessary schemata.

Achievement and Graph Comprehension

In agreement with other researchers who explored reading and arithmetic achievement in relation to graph comprehension (Goetsch, 1936; Herrmann, 1976; Johnson, 1971), it was found that ability to comprehend the mathematical relationships expressed in graphs is positively correlated with mathematics and reading achievement. This finding is not surprising since reading and mathematics achievement are global predictors of success in school-related tasks, which include graph reading and comprehension.

Implications. The results of this study suggested that other factors be considered when examining graph comprehension. For fourth-

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graders, these factors include prior knowledge of the topic of the graph, prior knowledge of mathematical content employed in the graph, and prior knowledge of the form of the graph. For seventh-graders, prior knowledge of mathematical content should be considered. Teachers might assess readiness for graph activities by constructing inventories to identify the relevant aspects of prior knowledge acquired by students prior to presenting the graph tasks. If there are any gaps in the students' graph schemata, pre-graph reading activities, described previously, might enhance children's readiness for comprehending graph-related tasks.

Sex-Related Differences

Sex-Related Differences with respect to Achievement

The results of this study support the previous research indicating that there are no significant sex-related differences in elementary school (Fennema, 1974a, 1978, 1980a; Skypek, 1980; Stroud & Lindquist, 1942; Swafford, 1980). Similar to other observations (Armstrong, 1975; Callahan & Glennon, 1975; Fennema, 1978; Waters, 1980), sex-related differences did appear to be more pronounced in early adolescence. However, the difference in mathematics achievement was in favor of the girls; i.e., seventh-grade girls significantly outperformed boys in mathematics achievement.

Implications. It is possible that this change in expected patterns of achievement, i.e., girls outperforming boys in mathematics achievement, might be attributed to women's changing role in society (Fennema & Sherman, 1978; Maccoby & Jacklin, 1974). Teachers should continue to equally encourage girls and boys to develop their reading and mathematics skills to their fullest potential. Caution should be taken so that cultural, sex-role stereotypes do not influence students' perceptions of different school-related tasks. For example, boys should be encouraged to develop their reading skills and not look upon reading as a "female domain." Girls should be encouraged to develop their mathematics skills and not look upon mathematics as a "male domain." The responsibility of promoting positive attitudes toward different school-related tasks cannot be limited to the classroom teacher. Parents must be recruited to reinforce these positive attitudes at home if they do not already do so.

Sex-Related Differences with respect to Prior Knowledge

With respect to prior knowledge, there is very little evidence of sex-related differences. However, topics that were neutral and free from sex-role stereotypes were selected purposely for this study and graphical form items were designed to be topic- and numerically content-free. No identification of significant sex-related differences with respect to prior knowledge of mathematical content might imply that girls and boys who were subjects in this study had similar or related experiences with this aspect of prior knowledge.

Sex-Related Differences with respect to Graph Comprehension

The results of this study support Strickland's (1938/1972) observations that there are no significant sex-related differences with respect to graph comprehension in fourth-grade. Testing and inspecting the seventh grade means of boys and girls yield the same results. It is possible that no significant sex-related differences occurred because graph test items were constructed to reflect three different levels of comprehension equally represented throughout the graph test, and graphs were designed to be neutral and free from sex-role stereotypes.

Implications. The possibility that sex-related differences might be attributed to school-related tasks that are either male- or female-oriented was suggested by some researchers (Asher, 1977; Fox, 1977; Graf & Riddell, 1972; Janvier, 1978; Johnson & Greenbaum, 1980; Leder, 1974; Schonberger, 1978). Similar to the attempts made in this study, efforts must be made to control school-related tasks so that these tasks do not favor boys or girls in competitive or norm-referenced situations (e.g., test items designed by test publishers and/or classroom teachers).

Recommendations for Future Research

Originally it was the intent of this study to examine minority group performance on comprehending the mathematical relationships expressed in graphs, but due to an inadequate representation of native-English-speaking minority students, this aspect of the problem had to be deleted (see The Sample, Chapter III, p. 52). Including minority group performance was a concern because many scientific and technologically-related occupations in which few minority groups are represented, rely upon knowledge of graphical forms (Chipman, Note 1). Therefore, it is important to determine whether ethnic/minority group members are being excluded from these fields because of an inadequate prior knowledge base to perform graph reading tasks. Studies that examine the effect of prior knowledge, ethnic/minority status, socio-economic status, and/or sex-related differences with respect to cultural background, on graph comprehension, should be conducted. Also, since reading graphs is a skill for functional literacy, examining an adult population using similar independent and dependent variables incorporated in this study, should be considered.

The development of spatial ability might account for sex-related differences between high school males and females (Fennema, 1974b, 1975b, 1977, 1980a; Maccoby & Jacklin, 1974). Also, there is controversy over the relationship between spatial ability and graph comprehension. Vernon (1946) who worked with adults and college students claimed that understanding and recalling information in graphical form was dependent upon spatial ability. On the other hand, Johnson (1971) observed that spatial ability did not uniquely contribute to predicting graph reading ability for middle-school children. It is possible that age might be a factor causing these differences. However, the relationships among spatial ability, sex, age, the three aspects of prior knowledge and graph comprehension should be examined.

As expected, the results of this study suggest developmental differences in graph reading ability between fourth- and seventh-graders. Perhaps seventh-graders have entered the Piagetian developmental stage of formal operations, which may have enabled them to explore the abstractions of communication in graphical form without a topic or graphical form prior knowledge base. The relationship between one aspect of Piaget's theory, "horizontal - vertical" concept development and graph comprehension, was examined by Herrmann (1976). Although his work attempted to explore concept development, only one age group was studied.

It is possible that building prior knowledge might enhance readiness for advancing from the stage of concrete operations to the stage of formal operations. Studies that examine the relationship among prior knowledge, the Piagetian stages of cognitive development, and graph reading ability should be conducted.

Some graph studies reviewed explored students' ability to retain the information in certain types of graphs under certain conditions (Herrmann, 1976; Price et al., 1974; Vernon, 1946, 1950, 1951, 1952; Washburne, 1927a, 1927b). However, some of the schema theory literature suggest that the hierarchical structure of one's schemata and relevant prior knowledge account for such retention (Anderson et al., 1978; Brown et al., 1977; Stein, 1978). Therefore, the relationship between prior knowledge and the amount of information retained after reading a graph should be explored.

There is evidence to support the influence of affective factors (e.g., interest) in the reader's ability to comprehend general written discourse (Sjogren & Timpson, 1979; Weber, 1979). Also, affective factors have been recognized as contributors to sex-related differences in mathematics (Aiken, 1974; Fennema, 1974b, 1978). Therefore, the relationship among affective factors (e.g., attitude towards mathematics in general and graphs in particular, including the topics of the graphs, and the graphical form), prior knowledge, and graph comprehension should be examined.

Teaching experiments similar to the ones conducted by Janvier (1978) should be conducted. At least two different approaches could be taken.

One approach might explore the effects of first building the prerequisite mathematical concepts to be employed in the graphs, and then presenting the graph-reading tasks to the children. Another approach might explore the effect of teaching the mathematical concepts in conjunction with graph reading skills by collecting "real-world" data, discussing the mathematical relationships, and depicting these relationships pictorially.

Experiments that employ other pre-graph reading sessions for building prior knowledge of the topic of the graphs, similar to Strickland's (1938/1972) study, should be conducted in a control/experimental setting, involving elementary school children. It may be that prior instruction in building prerequisite knowledge might be adequate for improving graph comprehension, and that comprehension is not limited to being a function of development.

Current research examining cognitive processes involved in graph comprehension is being undertaken (Consulting Statisticians, Inc., Note 11). Further studies that explore the strategies employed by children that aid them in tapping any or all of the three aspects of prior knowledge should be conducted. One aspect of this type of research worth investigating is the existence of surface and deep structures of graphs, suggested as a result of the present study. The surface structure of graphs might include the explicitly stated topic of the graph and the graphical form. The deep structure might be composed of the implicitly stated mathematical relationships. The ability to retrieve information needed for comprehending the message in a graph might be dependent upon whether relevant cues are located in the surface structure or the deep structure of the graph. The validity of this model must be tested.

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Appendix A

Graph Test Objectives

Graph Test

Graph Test Answer Key

Instructions for Administering the Graph Test

Graph Test Objectives

I. General Objectives

1. To describe the data literally by identifying or recognizing the data in the graph that answer *textually explicit* questions.
2. To analyze the mathematical relationships between and among data by interpreting and integrating the data in the graph to answer *textually implicit* questions.
3. To infer from, predict from, and extend the data, by analyzing the mathematical relationships between and among the data to answer *scriptally implicit* questions.

II. Specific Objectives

		GRAPH
1.	To add whole numbers	1,4,5,10,12
2.	To subtract whole numbers	1,4,6,10,11,12
3.	To multiply whole numbers	1,2,6,10,11,12
4.	To divide whole numbers	11
5.	To compare whole numbers	4,5,6,7,10,11,12
6.	To multiply numbers including fractions	10,11,12
7.	To express the fractional part of a total amount, given a part of that amount	2,3
8.	To calculate the percent of a given amount	3
9.	To calculate the percent, given a number and a part	7
10.	To calculate a total amount of money expressed in cents	1
11.	To compare time readings	8
12.	To compare monetary value	1
13.	To identify the number of hours in one day	2
14.	To identify the number of days in one week or part of one week	1,2
15.	To translate "one billion" to a numeral	3
16.	To calculate the amount of time (in hours) between two time readings expressed in standard form (e.g., 8:30 P.M.)	8
17.	To compare trillions of dollars expressed in decimal form	9
18.	To identify the number of weeks in one month	11
19.	To identify the number of months in one year	11

ERIC

Graph Test Objectives - Continued

	GRAPH
20. To calculate an amount of money constant over a period of time	1
21. To calculate the probability of an event	5,12
22. To determine when data is increasing, decreasing, or remaining the same	7,8,9,10

III. Item Objectives

1. For each of the twelve graphs, item #1 and item #2 measured *textually explicit* (task a) comprehension.

2. For each of the twelve graphs, item #3 and item #4 measured *textually implicit* (task b) comprehension.

3. For each of the twelve graphs, item #5 and item #6 measured *scriptally implicit* (task c) comprehension.

NAME ______________________ DATE ______________ FORM _____ SCORE _____

This booklet contains 12 graphs.[1] Each graph has 6 questions. Read each question carefully and THINK before answering. You may find some questions to be more difficult than others. Try to do your best and answer all of the questions.

DIRECTIONS: For each question, select the letter in front of the choice that best answers the question and place it in the space provided near the question. Your scrap work may be done in the booklet. As you complete the questions for each graph, go ahead to the next page. If you should finish before time is up, go back and check your work.

Thank you for your cooperation and participating in this research study.

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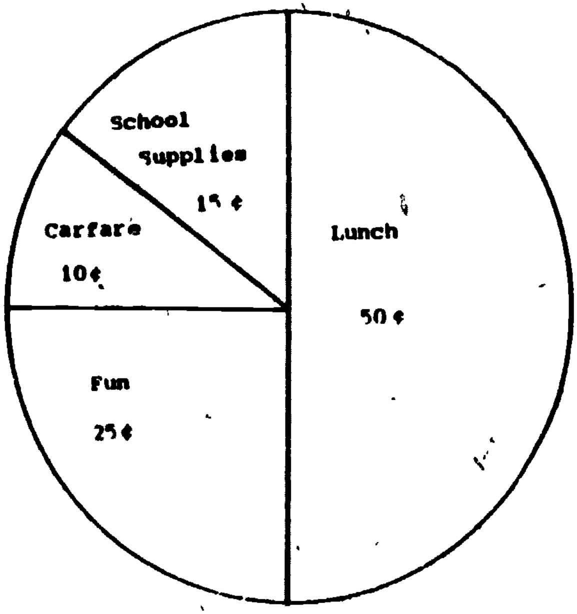
[1] Graphs 2 through 12 are 85% reductions of those presented to students. Reductions were made to meet margin requirements.

Graph 1

HOW JOHN SPENDS HIS DAILY SCHOOL ALLOWANCE



USE THE GRAPH ABOVE TO ANSWER THE FOLLOWING QUESTIONS.

1. What does this graph tell you?
   a. The way John spends his money on weekends
   b. The way John spends his money during one complete week
   c. The way John spends his money for vacations
   d. The way John spends his money for one school day

1. ___

2. How much does John spend on school supplies for one day?
   a. 10¢
   b. 15¢
   c. 25¢
   d. 50¢

2. ___

3. What is the total of John's daily school allowance?
   a. $ .95
   b. $1.00
   c. $1.50
   d. $2.00

3. ___

4. How much more does John spend on lunch than on carfare?
   a. 25¢
   b. 35¢
   c. 40¢
   d. 60¢

4. ___

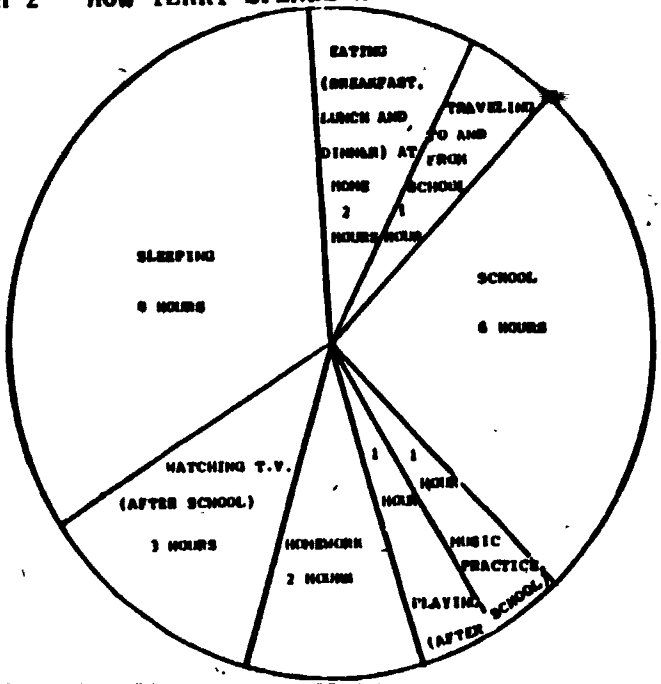
5. How much money does John need to pay for lunch for five school days?
   a. 50¢
   b. $1.00
   c. $2.00
   d. $2.50

5. ___

6. What is the total amount of money John needs for five school days?
   a. $1.00
   b. $3.50
   c. $5.00
   d. $7.00

6. ___

Graph 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

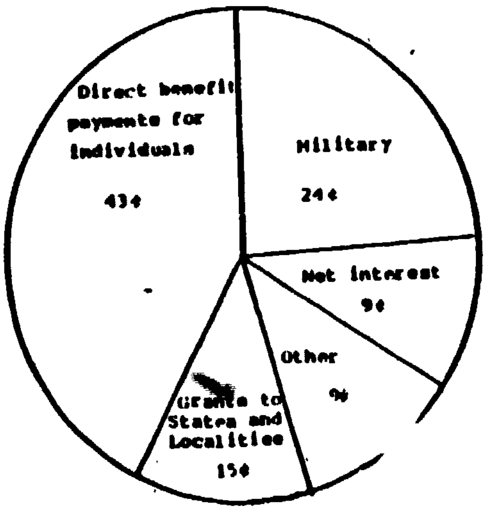
5. ____

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. ____

ERIC Full Text Provided by ERIC

Graph 3 THE U.S. GOVERNMENT'S 1981 DOLLAR BUDGET



USE THE GRAPH ABOVE TO ANSWER THE FOLLOWING QUESTIONS.

1. What does this graph tell you?
   a. The value of the U.S. dollar in 1981
   b. In 1981, the U.S. will have only $1.00 to spend
   c. How each dollar is going to be broken up to support the country in 1981
   d. In 1981, the U.S. Government will spend $1.00 at a time

1. ___

2. How much money out of every dollar will the U.S. Government spend on net interest?
   a. 9¢ c. 24¢
   b. 15¢ d. 43¢

2. ___

3. What fractional part of each dollar will the U.S. Government spend on net interest?
   a. $\frac{1}{9}$ c. $\frac{100}{9}$
   b. $\frac{9}{100}$ d. 9

3. ___

4. Which of the following would be classified under "other" spending?
   a. Supporting foreign commitments
   b. The President's salary
   c. Purchasing tanks
   d. Grants to cities

4. ___

5. If the U.S. Government is going to spend one billion dollars in 1981, how much of it will be spent for grants to states and localities?
   a. $150 thousand c. $150 billion
   b. $150 million d. $150 trillion

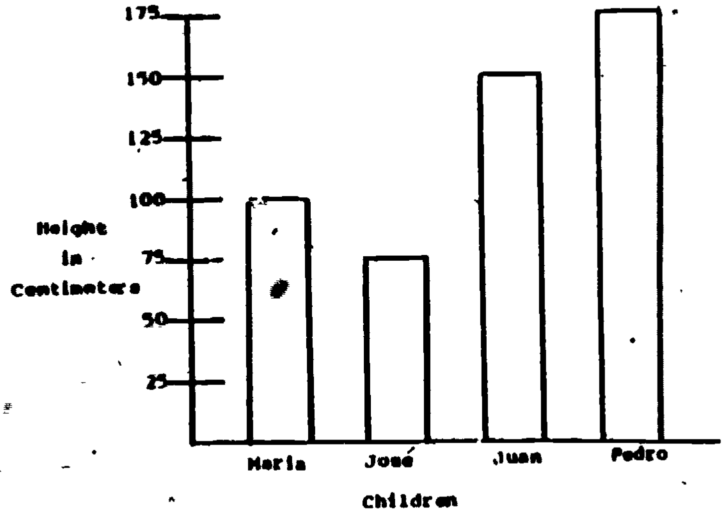
5. ___

6. According to the projected 1981 budget, which of the following appears to be correct?
   a. There is a greater need to support military defense than direct benefit payments for individuals
   b. There is a greater need to support military defense than aiding states and localities
   c. There is a greater need to support foreign commitments than military defense
   d. There is a greater need to support foreign commitments than direct benefit payments for individuals

6. ___

ERIC Full Text Provided by ERIC

Graph 4 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 Juan than José?
   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 20 centimeters
   b. José will be taller by 20 centimeters
   c. Maria will be taller by 5 centimeters
   d. José will be taller by 5 centimeters

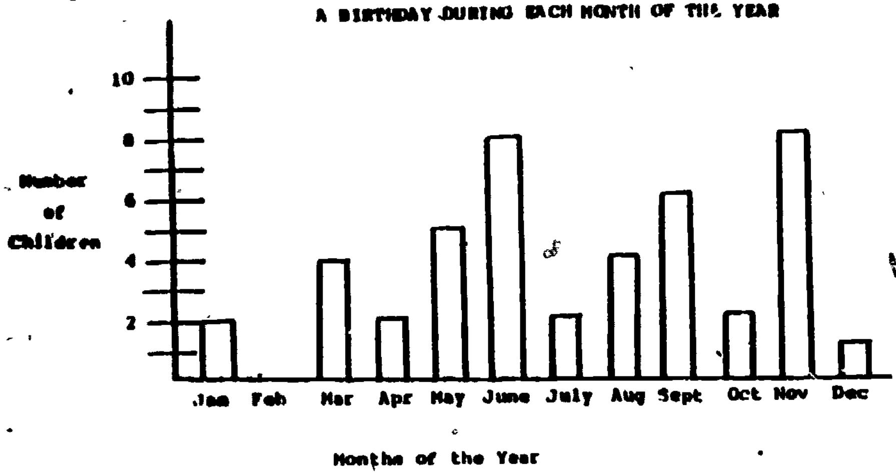
5. ___

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. ___

Graph 5

THE NUMBER OF CHILDREN IN MR. KAHN'S CLASS CELEBRATING A BIRTHDAY DURING EACH MONTH OF THE YEAR



USE THE GRAPH ABOVE TO ANSWER THE FOLLOWING QUESTIONS.

1. How many children celebrate a birthday in February?
   a. 0 c. 2
   b. 1 d. 4

1. ___

2. During which month are there eight children who celebrate a birthday?
   a. May
   b. July
   c. September
   d. November

2. ___

3. What does this graph tell you?
   a. There are more birthdays during June and November than during any other month of the year
   b. There are more birthdays during May than during any other month of the year
   c. There are the least number of birthdays during June and November than during any other month of the year
   d. As the year progresses from January to December, the number of birthdays decreases

3. ___

4. How many children are in Mr. Kahn's class?
   a. 10 c. 44
   b. 30 d. 55

4. ___

5. What is the probability that the birthday being celebrated in December occurs on December 25th?
   a. $\frac{1}{31}$ c. $\frac{30}{31}$
   b. $\frac{25}{31}$ d. 1

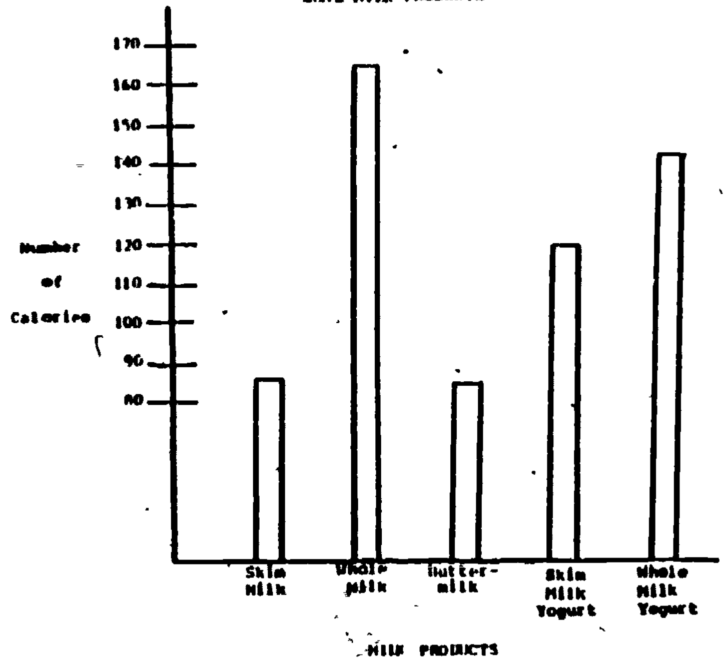
5. ___

6. Sally's birthday is in February. According to the graph, which of the following statements is correct?
   a. Sally was probably born on February 29th
   b. Sally is not in Mr. Kahn's class
   c. Sally is in Mr. Kahn's class
   d. Sally is the only one celebrating a birthday in February

6. ___

Graph 6

THE NUMBER OF CALORIES IN ONE CUP OF SOME MILK PRODUCTS



USE THE GRAPH ABOVE TO ANSWER THE FOLLOWING QUESTIONS.

1. What does this graph tell you?
   a. The number of vitamins in one cup of some milk products
   b. The price of one cup of some milk products
   c. The weight of one cup of some milk products
   d. The number of calories in on cup of some milk products

1. ___

2. How many calories are contained in one cup of Skim Milk?
   a. 80 c. 90
   b. 87 d. 120

2. ___

3. One cup of which milk product contains the <u>fewest</u> number of calories?
   a. Skim Milk Yogurt
   b. Whole Milk
   c. Buttermilk
   d. Whole Milk Yogurt

3. ___

4. According to the graph, which of the following statements is correct?
   a. Whole milk products contain fewer calories than skim milk products
   b. Whole milk products contain more calories than skim milk products
   c. Both whole milk yogurt and skim milk yogurt contain fewer calories than skim milk
   d. Whole milk products contain the same amount of calories as skim milk products

4. ___

5. If you were to go on a low-calorie diet, according to the graph, which milk product would be the best to include in your diet?
   a. Skim milk
   b. Skim milk yogurt
   c. Whole milk
   d. Whole milk yogurt

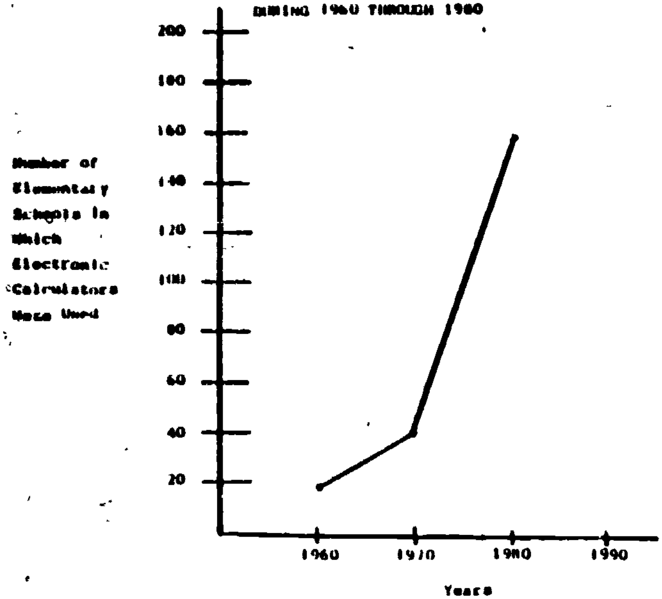
5. ___

6. Which of the following questions <u>cannot</u> be answered from reading the graph?
   a. How many calories less is one cup of whole milk yogurt than one cup of whole milk?
   b. How many calories would you expect there to be in four cups of whole milk?
   c. Why does one cup of yogurt made with skim milk have more calories than one cup of skim milk, but one cup of yogurt made with whole milk have less calories than one cup of whole milk?
   d. If you made two milkshakes with the same ingredients, except one was made with one cup of buttermilk, and the other with one cup of skim milk, which would have less calories?

6. ___

Graph 7

THE NUMBER OF 200 BROOKLYN ELEMENTARY SCHOOLS IN WHICH ELECTRONIC CALCULATORS WERE USED DURING 1960 THROUGH 1980



USE THE GRAPH ABOVE TO ANSWER THE FOLLOWING QUESTIONS.

1. In how many elementary schools were electronic calculators used during 1970?

   a. 0   c. 10
   b. 20   d. 40

   1. ___

2. According to the graph, what is the total number of elementary schools in Brooklyn?

   a. 160   c. 220
   b. 200   d. 1,100

   2. ___

3. Which of the following expresses what happened to the number of electronic calculators in use, as the years progressed from 1960 to 1980?

   a. The number of schools in which the calculator was used decreased
   b. The number of schools in which the calculator was used increased
   c. The number of schools in which the calculator was used remained the same
   d. The number of schools in which the calculator was used decreased and then increased

   3. ___

4. In what percent of the schools were the electronic calculators used in 1970?

   a. 18%   c. 40%
   b. 20%   d. 100%

   4. ___

5. If we look ahead to 1990, in how many Brooklyn elementary schools would you expect to find the electronic calculator used?

   a. exactly 160
   b. less than 100
   c. more than 160
   d. more than 100 but less than 160

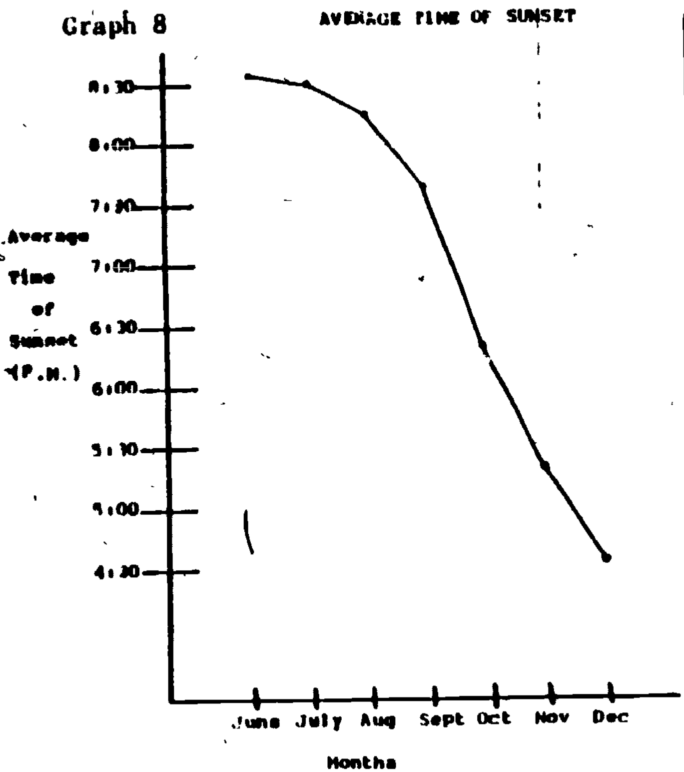
   5. ___

6. Which of the following changes from 1960 to 1980 would you expect to be true, based on the information in the graph?

   a. Children do not know the times tables as well as they used to
   b. Children enjoy math more than they used to
   c. Children are learning math better now than they used to
   d. More children have calculators available to them now than ever before

   6. ___

Graph 8



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.
   - b. 5:15 P.M.
   - c. 6:15 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
   - b. $1\frac{1}{2}$ hours
   - c. $2\frac{1}{4}$ hours
   - d. 3 hours

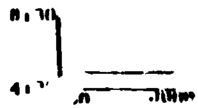
4. ___

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?

a. Average Time of Sunset (P.M.)

b. Average Time of Sunset (P.M.)

c. Average Time of Sunset (P.M.)



d. Average Time of Sunset (P.M.)

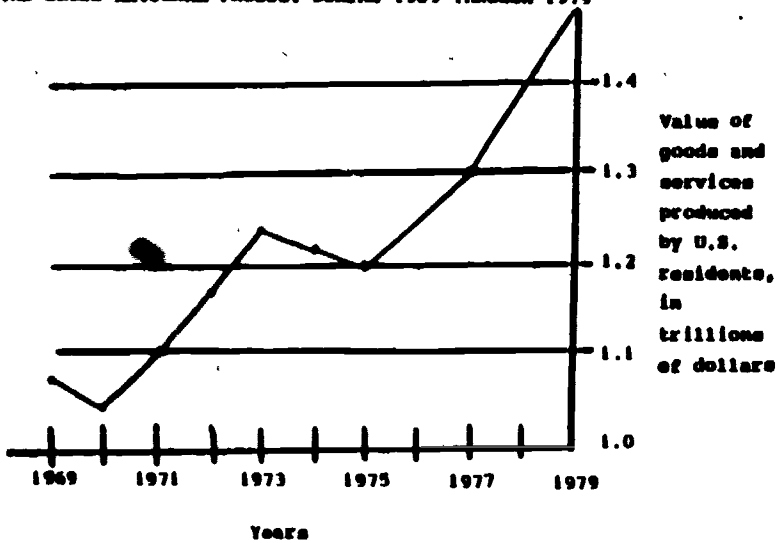
5. ___

6. As the months progress from June to December, the average time of sunrise 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

6. ___

Graph 9

THE GROSS NATIONAL PRODUCT DURING 1969 THROUGH 1979



USE THE GRAPH ABOVE TO ANSWER THE FOLLOWING QUESTIONS.

1. What was the value of goods and services produced by U.S. residents in 1971?
   a. $1.0
   b. $1.1
   c. $1.1 trillion
   d. $1.2 trillion

1. ____

2. In what year was the Gross National Product $1.3 trillion?
   a. 1971 c. 1976
   b. 1975 d. 1977

2. ____

3. What year represents the lowest Gross National Product?
   a. 1969 c. 1975
   b. 1970 d. 1979

3. ____

4. A recession occurred in 1969 to 1970 and 1973 to 1974. How does a recession affect the Gross National Product?
   a. Value of goods and services increase
   b. Value of goods and services decrease
   c. Value of goods and services remain the same
   d. Value of goods and services increase and then decrease

4. ____

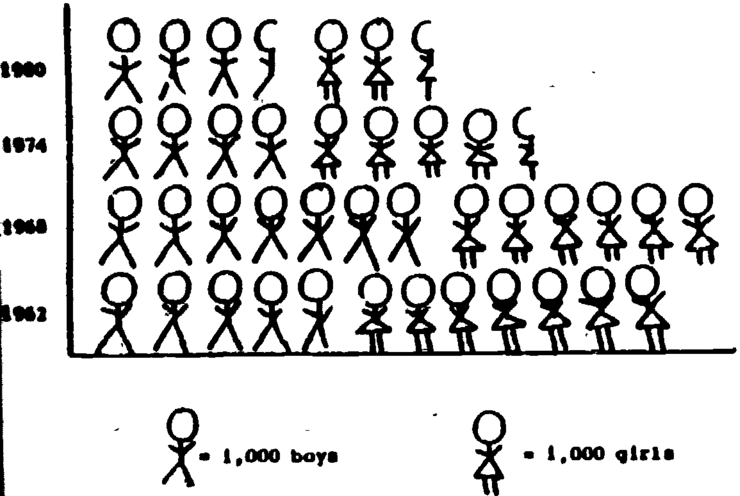
5. If a recession occurs during 1980, what would you expect to happen to the Gross National Product?
   a. Increase
   b. Decrease
   c. Remain the same
   d. Increase and then decrease

5. ____

6. Following the information in the graph, what would you expect to happen in 1980 (provided there is no recession)?
   a. The Gross National Product would increase
   b. The Gross National Product would decrease
   c. The Gross National Product would remain the same
   d. The Gross National Product would decrease and then increase

6. ____

Graph 10 FIRST GRADE ENROLLMENT IN ONE BROOKLYN SCHOOL DISTRICT IN 1962, 1968, 1974 AND 1980



USE THE GRAPH ABOVE TO ANSWER THE FOLLOWING QUESTIONS.

1. What does this graph tell you?
   a. The number of boys and girls in the first grade during 1962, 1968, 1974 and 1980 in a Brooklyn School District
   b. The number of boys and girls getting promoted in one Brooklyn School District during 1962, 1968, 1974 and 1980
   c. The number of boys and girls graduating from elementary schools in one Brooklyn School District during 1962, 1968, 1974 and 1980
   d. The number of boys and girls in one Brooklyn School District

1. ____

2. How many boys were in the first grade in 1968?
   a. 7 c. 7,000
   b. 13 d. 13,000

2. ____

3. In what year was there the fewest number of children in first grade?
   a. 1962 c. 1974
   b. 1968 d. 1980

3. ____

4. How did the first grade population change from 1968 to 1974?
   a. The total number of children increased
   b. The total number of children decreased
   c. The number of girls increased
   d. The number of boys increased

4. ____

5. If no children move out of Brooklyn, no new children move into Brooklyn, and no children are held over, in what year would the fewest number of children graduate from sixth grade?
   a. 1968 c. 1980
   b. 1974 d. 1986

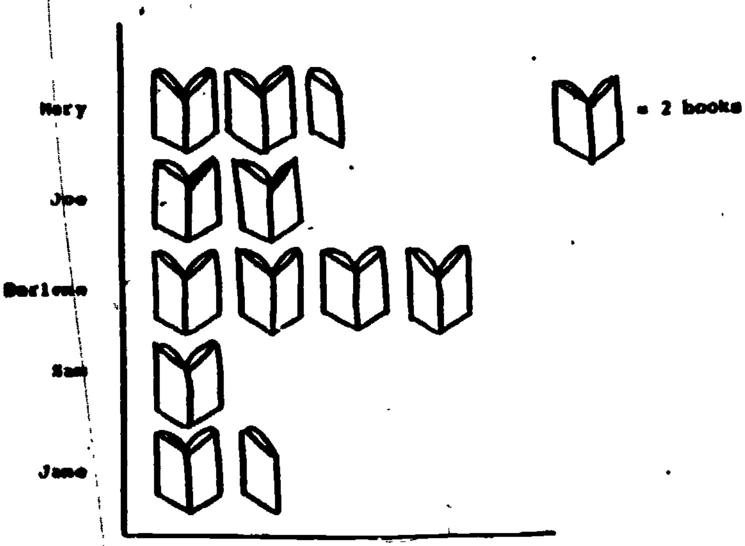
5. ____

6. How many children would you expect to be in the first grade in this Brooklyn School District in 1986 if the 1974-1980 trend continues?
   a. 6,000
   b. More than 6,000
   c. Fewer than 6,000 but more than 3,000
   d. Fewer than 3,000

6. ____

Graph 11

THE NUMBER OF BOOKS THE JONES CHILDREN READ PER MONTH



USE THE GRAPH ABOVE TO ANSWER THE FOLLOWING QUESTIONS.

1. How many books did Sam read in one month?
   a. 0
   b. 1
   c. $1\frac{1}{2}$
   d. 2

1. ____

2. Who read $2\frac{1}{2}$ books in one month?
   a. Mary
   b. Jane
   c. Joe
   d. No one

2. ____

3. Who read the **least** number of books in one month?
   a. Darlene
   b. Sam
   c. Jane
   d. Joe

3. ____

4. In one month, how many more books did Darlene read than Jane?
   a. $1\frac{1}{2}$
   b. $2\frac{1}{2}$
   c. 5
   d. $5\frac{1}{2}$

4. ____

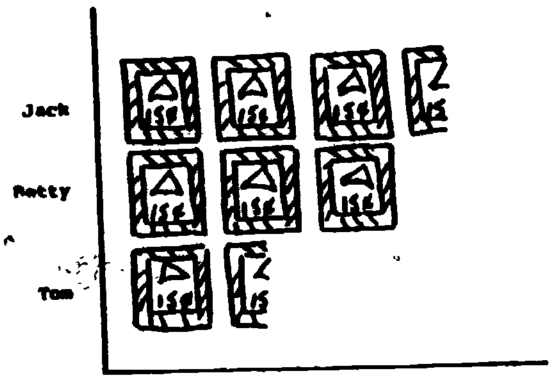
5. At the end of one year, about how many books will Joe have read?
   a. 16
   b. 24
   c. $30\frac{1}{2}$
   d. 48

5. ____

6. About how many books does Darlene read in one week?
   a. 1
   b. 2
   c. 4
   d. 8

6. ____

Graph 12 STAMPS COLLECTED BY CHILDREN



 = 4 stamps

USE THE GRAPH ABOVE TO ANSWER THE FOLLOWING QUESTIONS.

1. What does each symbol  represent?
   a. One stamp
   b. One-half of a stamp
   c. Four stamps
   d. Fifteen stamps

1. ____

2. How many stamps has Tom collected?
   a. $1\frac{1}{2}$ c. $22\frac{1}{2}$
   b. 6   d. 30

2. ____

3. How many more stamps has Betty collected than Tom?
   a. $1\frac{1}{2}$ c. 6
   b. 3   d. $22\frac{1}{2}$

3. ____

4. According to the graph, which of the following statements is true?
   a. Jack has $\frac{1}{2}$ more stamps than Betty
   b. Tom has 8 fewer stamps than Jack
   c. Betty has $1\frac{1}{2}$ more stamps than Tom
   d. Betty has 45¢ worth of stamps

4. ____

5. If the children sold their stamps for the value on the face of the stamp, who, if any of the children, would be able to buy a new bicycle using this money?
   a. Tom   c. Jack
   b. Betty   d. None of the children

5. ____

6. One of Tom's stamps is rare, but he doesn't know it. He and Betty are going to trade one stamp for one stamp. What is the probability that Betty receives Tom's rare stamp?
   a. $\frac{1}{2}$ c. $\frac{1}{6}$
   b. $\frac{1}{12}$ d. $\frac{1}{18}$

6. ____

Graph Test Answer Key

Graph 1	Graph 2	Graph 3	Graph 4	Graph 5
1. d	1. b	1. c	1. c	1. a
2. b	2. d	2. a	2. c	2. d
3. b	3. a	3. b	3. b	3. a
4. c	4. b	4. a	4. d	4. c
5. d	5. c	5. b	5. a	5. a
6. c	6. d	6. b	6. b	6. b

Graph 6	Graph 7	Graph 8	Graph 9	Graph 10
1. d	1. d	1. c	1. c	1. a
2. b	2. b	2. c	2. d	2. c
3. c	3. b	3. a	3. b	3. d
4. b	4. b	4. c	4. b	4. b
5. a	5. c	5. b	5. b	5. d
6. c	6. d	6. b	6. a	6. c

Graph 11	Graph 12
1. d	1. c
2. d	2. b
3. b	3. c
4. c	4. b
5. d	5. d
6. b	6. c

Instructions for Administering the Graph Test

1. Check students' seating arrangement.
2. Each student who has parental consent should receive a pencil and a test booklet. You should have received a roster with this information.
3. For your own information, there are ten different forms of the Graph Test. Each form has the twelve graphs arranged in different order.
4. Read the following italicized instructions aloud to students:

Good morning.

You are again being asked to participate in a research study to help determine how children read graphs. Your results will be helping us to help children improve their graph reading skills.

Today is the last of four sessions. Remember, the results of the tests will not affect your marks in school, but please try to do your best and answer all of the questions.

Print your first name and your last name in the space provided on the cover sheet. Also, write today's date, which is _____, in the space provided. Read the directions silently as I read them aloud to you:

> *This booklet contains 12 graphs. Each graph has 6 questions. Read each question carefully and THINK before answering. You may find some questions to be more difficult than others. Try to do your best and answer all of the questions.*
>
> *DIRECTIONS: For each question, select the letter in front of the choice that best answers the question and place it in the space provided near the question.*

Have the following example ready on the chalkboard:

S1. 7 + 4 =

a. 9

b. 10

c. 11

d. 12 *S1. c*

The correct choice is c. You would write "c" in the space provided.

Graph Test - Administration Instructions - Continued

Your scrap work may be done in the booklet. As you complete the questions for each graph, go ahead to the next page. You will have 1 hour to complete this test. If you should finish before time is up, go back and check your work.
Thank you for your cooperation and participating in this research study.

Are there any questions?

Open your booklet to the first page, and begin.

6. Keep the time posted on the chalkboard.
7. Inform the students when there is ten minutes left; one minute left.
8. When time is up, read the following aloud to the students:

Stop work. Pencils down. Close your booklets. Pass your booklet to the ___ (front, left, right).

Instruct students to pass their booklets to the front or the left or the right, which ever is appropriate or convenient for you.

Be sure to collect all pencils!

Appendix B

Prior Knowledge Inventory

Prior Knowledge Inventory Answer Key

Instructions for Administering the Prior Knowledge Inventory

ERIC

NAME ______________________ DATE __________ FORM ___

In sentences A and B, please check the part that applies to you:

A. I am a ____ boy.
____ girl.

B. At home, I ____ do NOT speak English. I speak another language.
____ speak English AND 1 or more other languages.
____ speak ONLY English.

This booklet contains three parts: Mathematical Content, Topic, and Graphical Form.[1] Don't worry if you do not understand these titles. Just read each question carefully and THINK before answering.

You may find some questions to be more difficult than others. Try to do your best and answer all of the questions.

DIRECTIONS: For each question, select the letter in front of the choice that best answers the question and place it in the space provided near the question. Your scrap work may be done in the booklet. As you complete each part, go ahead to the next page. If you should finish before time is up, go back and check your work.

Thank you for your cooperation and participating in this research study.

FOR OFFICE USE ONLY:

STATUS	M.C.	T	G.F.	TOTAL
____	____	____	____	____

[1]The following pages are 88.6% reductions of those presented to students. Reductions were made to meet margin requirements.

PART ___. MATHEMATICAL CONTENT

1. 2+4+2+5+8+2+4+6+2+8+1=

a. 10 c. 44
b. 30 d. 55

1. ____

2. Which of the following is a correct statement?

a. 1 centimeter is greater than 1 inch
b. 1 inch is less than 1 centimeter
c. 1 inch equals 1 centimeter
d. 1 centimeter is less than 1 inch

2. ____

3. Which of the following statements is correct?

a. 87 is less than 120
b. 120 is less than 87
c. 87 is greater than 140
d. 87 is greater than 160

3. ____

4. How many hours are there in one day?

a. 8 hours
b. 10 hours
c. 12 hours
d. 24 hours

4. ____

5. $3\frac{1}{2} \times 4 =$

a. 10 c. 14
b. 12 d. 16

5. ____

6. What is the total number of days in December?

a. 28 c. 30
b. 29 d. 31

6. ____

7. If a child is born in December, what is the probability that the child has a birthday on December 15th?

a. $\frac{1}{31}$ c. $\frac{15}{31}$
b. $\frac{1}{15}$ d. 1

7. ____

8. Which of the following statements is correct?

a. 140 is less than 120
b. 120 is greater than 140
c. 87 is greater than 120
d. 160 is greater than 120

8. ____

9. 15¢ x 14 =

a. $.21 c. $2.10
b. $1.90 d. $3.10

9. ____

CONTINUED

ERIC

10. Which of the following statements is correct?

a. 160 is less than 40
b. 160 is greater than 40
c. 20 is greater than 40
d. 40 is less than 20

10. ____

11. Which of the following is the numeral representing one billion?

a. 1,000
b. 1,000,000
c. 1,000,000,000
d. 1,000,000,000,000

11. ____

12. What fractional part of 100 is 9?

a. $\frac{100}{9}$ c. $\frac{1}{9}$
b. $\frac{9}{100}$ d. $\frac{9}{1}$

12. ____

13. What is 15% of one billion?

a. 150 thousand
b. 150 million
c. 150 billion
d. 150 trillion

13. ____

14. 40 is what percent of 200?

a. 18% c. 40%
b. 20% d. 100%

14. ____

15. Which of the following is the numeral for one trillion?

a. 1,000
b. 1,000,000
c. 1,000,000,000
d. 1,000,000,000,000

15. ____

16. Which of the following statements is correct?

a. 8:30 P.M. is earlier than 4:30 A.M.
b. 4:30 A.M. is later than 8:30 A.M.
c. 8:30 P.M. is later than 4:30 P.M.
d. 6:00 P.M. is earlier than 4:30 A.M.

16. ____

17. How much time is it from 6:15 P.M. to 8:30 P.M.?

a. $1\frac{1}{4}$ hours c. $2\frac{1}{4}$ hours
b. $1\frac{1}{2}$ hours d. 3 hours

17. ____

18. 75 + 10 =

a. 76 c. 175
b. 85 d. 750

18. ____

19. 160 - 140 =

a. 10 c. 120
b. 20 d. 200

19. ____

CONTINUED

20. How many days are there in one school week (not including Saturday and Sunday)?

a. 4 days c. 7 days
b. 5 days d. 10 days

20. _____

21. 7 x 1,000 =

a. 70 c. 7000
b. 700 d. 70,000

21. _____

22. 160 x 4 =

a. 64 c. 240
b. 100 d. 640

22. _____

23. 150 - 75 =

a. 25 c. 75
b. 50 d. 85

23. _____

24. 5 x 50¢ =

a. $.25 c. $25.00
b. $2.50 d. $250.00

24. _____

25. Which of the following is the closest number of weeks in one month?

a. 4 c. 12
b. 7 d. 52

25. _____

26. 15¢ x 12 =

a. $.18 c. $1.80
b. $1.70 d. $2.80

26. _____

27. 5 x $1.00 =

a. $.50 c. $ 50.00
b. $5.00 d. $500.00

27. _____

28. 100 ÷ 5 =

a. 105 c. 500
b. 150 d. 600

28. _____

29. What fractional part of 24 is 6?

a. $\frac{24}{6}$ c. $\frac{1}{4}$
b. $\frac{4}{1}$ d. $\frac{1}{12}$

29. _____

30. Which of the following is the numeral for 1.2 trillion?

a. 1,200,000
b. 1,000,200,000
c. 1,020,000,000
d. 1,200,000,000,000

30. _____

31. 4 x 1,000 =

a. 40 c. 4,000
b. 400 d. 40,000

31. _____

CONTINUED

32. 6,000 + 7,000 =

a. 1,300 c. 12,000
b. 13,000 d. 14,000

32. ____

33. 50¢ - 10¢ =

a. 25¢ c. 40¢
b. 35¢ d. 60¢

33. ____

34. 4 x 2 =

a. 6 c. 10
b. 8 d. 12

34. ____

35. Which of the following statements is correct?

a. 13,000 is less than 8,500
b. 8,500 is greater than 13,000
c. 8,000 is greater than 13,000
d. 13,000 is greater than 8,500

35. ____

36. 15¢ x 6 =

a. $.60 c. $9.00
b. $.90 d. $10.00

36. ____

37. 105 - 85 =

a. 20 c. 80
b. 25 d. 190

37. ____

38. 15¢ + 25¢ + 50¢ + 10¢ =

a. $.95 c. $1.50
b. $1.00 d. $2.00

38. ____

39. Which of the following expresses the numeral for 1.1 trillion?

a. 1,100,000
b. 1,010,000,000
c. 1,000,000,000,001
d. 1,100,000,000,000

39. ____

40. 5 x 2 =

a. 3 c. 10
b. 7 d. 20

40. ____

41. 5 x 24 =

a. 29 c. 120
b. 104 d. 130

41. ____

42. Which of the following statements is correct?

a. 8 is greater than 6
b. 6 is greater than 8
c. 8 is less than 6
d. 8 is less than 3

42. ____

CONTINUED

43. Which of the following statements is correct?

a. 87 does not equal 87
b. 87 is greater than 87
c. 87 is less than 87
d. 87 is equal to 87

43 ____

44. 1980 + 6 =

a. 1986 c. 2580
b. 2046 d. 7980

44. ____

45. What fractional part of 120 is 40?

a. $\frac{120}{40}$ c. $\frac{1}{3}$
b. $\frac{3}{1}$ d. $\frac{1}{5}$

45. ____

46. If there are five black marbles and one white marble in a jar and you reach in (without looking) and pull one out, what is the probability of selecting the white marble?

a. $\frac{1}{6}$ c. $\frac{1}{2}$
b. $\frac{1}{5}$ d. 1

46. ____

47. 3 x 4 =

a. 1 c. 12
b. 7 d. 15

47. ____

48. Which of the following statements is correct?

a. 1.2 trillion is greater than 1.24 trillion
b. 1.24 trillion is less than 1.2 trillion
c. 1.2 trillion is less than 1.24 trillion
d. 1.1 trillion is greater than 1.24 trillion

48. ____

49. 8 x 5 =

a. 3 c. 30
b. 13 d. 40

49. ____

50. 4,000 + 4,500 =

a. 850 c. 8,500
b. 4,900 d. 9,000

50. ____

51. $1\frac{1}{2}$ x 2 =

a. 1 c. 2
b. $\frac{4}{3}$ d. 3

51. ____

52. 6 x 1,000 =

a. 60 c. 6,000
b. 600 d. 60,000

52. ____

53. 8 ÷ 4 =

a. $\frac{1}{2}$ c. 4
b. 2 d. 32

53. ____

CONTINUED

54. How many months are there in one year?

a. 4 c. 12
b. 7 d. 52

54. ____

55. $1\frac{1}{2} \times 4 =$

a. 4 c. 5
b. $4\frac{1}{2}$ d. 6

55. ____

56. $1 \times 2 =$

a. $\frac{1}{2}$ c. 2
b. 1 d. 3

56. ____

57. $8 - 3 =$

a. 4 c. 6
b. 5 d. 24

57. ____

58. $2 \times 2 =$

a. 1 c. 4
b. 2 d. 8

58. ____

59. $12 - 6 =$

a. $\frac{1}{2}$ c. 6
b. 2 d. 10

59. ____

60. $2\frac{1}{2} \div 2 =$

a. $\frac{1}{2}$ c. $4\frac{1}{2}$
b. $\frac{5}{4}$ d. 5

60. ____

61. $4\frac{1}{2} \times 1{,}000 =$

a. 45 c. $4\frac{1}{2}000$
b. 450 d. 4,500

61. ____

62. $4 \times 12 =$

a. 3 c. 40
b. 16 d. 48

62. ____

63. $14 - 6 =$

a. $2\frac{2}{6}$ c. 20
b. 8 d. 84

63. ____

64. Which of the following is a correct statement?

a. 8 is less than 2
b. 3 is less than 2
c. 4 is less than 3
d. 2 is less than 3

64. ____

ERIC

PART __. TOPIC

1. Which of the following is an example of the United States supporting foreign commitments?
   - a. Giving grants to New York City and Miami
   - b. Helping South Viet Nam
   - c. Paying President Carter's salary
   - d. Purchasing tanks and weapons for the U.S. Army

1. ______

2. If a child begins school in the first grade, how many years later will he be in the sixth grade (if he does not get held over)?[1]
   - a. 1 year
   - b. 3 years
   - c. 6 years
   - d. 8 years

2. ______

[1] The correct answer, 5, was inadvertently omitted from the list of distractors. This oversight was identified after the testing was completed. Children's responses were probably not adversely affected since "c" is the closest choice, and assumed to be the correct answer.

3. What does "recession" mean in the following sentence?

   President Carter has placed the U.S. economy in a state of recession.
   - a. An increase in business activity
   - b. A decrease in business activity
   - c. An increase in the number of jobs available
   - d. A decrease in the number of states in the United States

3. ______

4. What does "probability" mean in the following sentence?

   The probability that heads appears when tossing a coin, is $\frac{1}{2}$.
   - a. The chance that heads will appear
   - b. The amount of time to toss the coin
   - c. The amount of money the coin is worth
   - d. The ability to toss the coin

4. ______

CONTINUED

5. Which of the following describes reading a book?

a. Looking at the first few pages and the last few pages
b. Concentrating on every sentence in every paragraph on every page to determine the meaning
c. Listening to someone's opinion about the book
d. Watching the story on television

5. ______

6. Which of the following statements is correct?

a. P.M. refers to morning time, A.M. refers to afternoon time
b. A.M. refers to night time
c. P.M. refers to morning and afternoon time
d. A.M. refers to morning time, P.M. refers to afternoon time

6. ______

7. What is a school district?

a. The principal of the school
b. The area in which schools are located, determining which children may attend
c. The area in which businesses are located and stores can be built
d. The teachers in the school

7. ______

8. What does "whole milk" mean in the following sentence?

The baby had to be given a special formula because he was allergic to whole milk.

a. Milk that has all its original ingredients
b. Milk that is treated with food coloring
c. Milk that is treated with sugar
d. Milk that is made with eggs

8. ______

9. What happens to the average number of daylight hours as the months progress from June to December?

a. Increases
b. Decreases
c. Remains the same
d. First decreases, then increases

9. ______

10. What is a calculator used for?

a. To determine a person's height
b. To determine a person's weight
c. To add, subtract, multiply and divide numbers
d. To answer questions about a story

10. ______

CONTINUED

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11. Which of the following describes an elementary school?

a. A school that has children in kindergarten, first, second, third, fourth, fifth and sixth grades
b. A school that has children in seventh, eighth, and ninth grades
c. A school that has only children who are three to five years old
d. A school that has children who are fifteen to eighteen years old

11. ______

12. How does a recession affect the Gross National Product?

a. It increases
b. It decreases
c. It remains the same
d. It increases and then decreases

12. ______

13. What does "buttermilk" mean in the following sentence?

My brother prefers to drink buttermilk with his lunch.

a. Milk made from butter
b. Liquid left after butter has been churned from the milk
c. Liquid left after cereal is eaten
d. Milk that takes the shape of butter

13. ______

14. What does "birthday" mean in the following sentence?

Susie will celebrate her birthday on July 4th.

a. Susie will be visiting her aunt
b. Susie will be one year older
c. Susie will get a lot of presents
d. Susie will have an ice cream cake

14. ______

15. What does "average" mean in the following sentence?

Jane's report card average is 95.

a. Jane received 95 in math
b. Adding all her marks and dividing by the number of marks, Jane received 95
c. Jane's highest score is 95
d. Jane's lowest score is 95

15. ______

16. What does "daily" mean in the following sentence?

Mom reads the newspaper daily to find out what food products are on sale.

a. Every year
b. Every month
c. Every week
d. Every day

16. _____

17. Purchasing guns, tanks and other weapons would be classified under which of the following?

a. Direct benefit payments to individuals
b. Military spending
c. Net interest
d. Other

17. _____

18. What does "allowance" mean in the following sentence?

After Tom mowed the lawn, Dad gave him his allowance.

a. Permission given to go somewhere or do something
b. A pet to care for and to play with
c. Money given to save or to spend
d. A letter to be written and mailed

18. _____

19. What does "skim milk" mean in the following sentence?

Mom bought skim milk because she is on a diet.

a. Milk that is treated with food coloring
b. Milk that is fattening
c. Milk that has the cream removed
d. Milk that is made with butter

19. _____

20. How can we determine who is the tallest in the class?

a. By eating a lot of food
b. By sleeping the most
c. By standing next to one another
d. By dressing properly

20. _____

21. What does "calories" mean in the following sentence?

Susan wondered about how many calories were in the piece of chocolate cake that she ate.

a. Unit of energy
b. Unit of weight
c. Unit of length
d. Unit of time

21. _____

CONTINUED

ERIC Full Text Provided by ERIC

22. If Frank is 175 cm. tall, how old do you think he is?

a. One year old
b. Five years old
c. Ten years old
d. Twenty years old

22. _____

23. What happens to the average time of sunset as the months progress from January to June?

a. It gets earlier
b. It gets later
c. It remains the same
d. It first gets earlier, and then gets later

23. _____

24. What does "budget" mean in the following sentence?

Every time mom gets her paycheck, she plans her budget.

a. Dinners for the week
b. How her money is to be spent
c. How much time she has
d. Appointments for the week

24. _____

25. What does "net interest" mean in the following sentence?

The net interest offered by the United States Government turned out to be 11%.

a. Showing concern and liking someone
b. The amount of money saved by U.S. citizens
c. The amount of trust that people have in the U.S. Government
d. Money added to the cost of U.S. Savings Bonds when cashed in

25. _____

26. When does sunrise occur?

a. In the morning
b. In the afternoon
c. In the evening
d. In the winter only

26. _____

27. Which of the following is NOT included as "school supplies"?

a. Pencils
b. Notebooks
c. Carfare
d. Erasers

27. _____

CONTINUED

28. What does "homework" mean in the following sentence?

It took Teddy three hours to do his science homework.

a. Work that Teddy's mother assigned him to do around the house
b. Work that Teddy's teacher assigned him to do at home
c. Work that Teddy's teacher assigned him to do in school
d. Work that Teddy's father assigned him to do outside the house

28. _____

29. When does sunset occur?

a. In the morning
b. In the summer only
c. In the evening
d. In the winter only

29. _____

30. What does "vitamins" mean in the following sentence?

Before eating breakfast, Andrew takes his vitamins.

a. Important exercise
b. Important organic compounds
c. Important food for energy
d. Important food for body building

30. _____

31. What does "enrollment" mean in the following sentence?

Little League enrollment has increased since last year.

a. The number of turns a player gets
b. The number of homeruns hit
c. The number of members belonging to or joining the league
d. The number of children leaving the league

31. _____

32. What does "height" mean in the following sentence?

In school today, the teacher measured Tommy's height.

a. How much Tommy weighs
b. How old Tommy is
c. How smart Tommy is
d. How tall Tommy is

32. _____

33. How much would you expect a new ten-speed bicycle to cost in a store?

a. Less than $5.00
b. More than $5.00, but less than $10.00
c. More than $10.00, but less than $20.00
d. More than $20.00

33. _____

CONTINUED

34. What does the term "Gross National Product" mean in the following sentence?

The Gross National Product was 1.2 trillion dollars in 1975.

a. A big product for the nation
b. The value of goods and services produced by U.S. residents
c. The value of money made by the federal government
d. The taxes collected by the federal government

34. _____

35. What is a low-calorie diet?

a. Eating foods that are fattening
b. Eating foods that are not fattening
c. Eating foods that have a lot of spices
d. Eating foods that have no vitamins

35. _____

36. Why would children want to read a lot of books?

a. To increase their running speed
b. To increase their knowledge
c. To increase the number of pets they have
d. To increase the amount of time they have to eat lunch

36. _____

37. During which month can you stay outside the longest because it gets dark the latest?

a. December
b. November
c. October
d. July

37. _____

38. For which activity is the most time spent?

a. Eating lunch
b. Sleeping
c. Doing homework
d. Playing outside

38. _____

CONTINUED

ERIC

39. What is a rare stamp?

a. A stamp that is widely used and available
b. A stamp that is one-of-a-kind and of great value
c. A stamp that is very cheap to buy
d. A stamp that can be bought in every post office

39. _____

40. What does "U.S. Government" mean in the following sentence?

The U.S. Government is very rich.

a. The President of the U.S.
b. The policemen who protect U.S. citizens
c. The collective organization that runs the U.S.
d. Each individual U.S. citizen

40. _____

41. Which of the following is NOT classified as "goods and services"?

a. Manufacturing pencils
b. Garbage collecting by government employees
c. Driving a car for pleasure
d. Teaching for a school system

41. _____

42. What does "carfare" mean in the following sentence?

Fred spends 50¢ a day for carfare to go to school.

a. Fred rides to school in a car worth 50¢
b. Fred spends 50¢ for transportation to school
c. Fred collects 50¢ for going to school
d. Fred pays 50¢ for lunch at school

42. _____

43. Stamp collecting is a hobby. What do people who collect stamps as a hobby do with the stamps?

a. Save or trade the stamps
b. Use the stamps to mail letters
c. Use the stamps to buy food
d. Draw pictures of the stamps

43. _____

44. President Carter's salary would be classified under which of the following?

a. Direct benefit payments to individuals
b. Military spending
c. Net interest
d. Other

44. _____

CONTINUED

45. The amount of money budgeted for certain items is dependent upon which of the following?

a. Need
b. Importance
c. Chance
d. Both (a) and (b)

45. ____

46. What does "weight" mean in the following sentence?

Martin did not want to eat the chocolate cake because he was worried about his weight.

a. How heavy he is
b. How tired he is
c. How sad he is
d. How smart he is

46. ____

47. What does "price" mean in the following sentence?

The price of the suit is $59.95.

a. Style
b. Color
c. Weight
d. Cost

47. ____

48. What does "graduate" mean in the following sentence?

After I graduate from high school, I will be going to college.

a. Become tired of doing homework
b. Successfully complete all courses and receive a diploma
c. Receive an award for playing basketball
d. Attend an assembly program

48. ____

49. What does "electronic calculator" mean in the following sentence?

My friend does his math homework using an electronic calculator.

a. A computing machine that runs on battery or electricity
b. A miniature electronic ping pong machine
c. A small computer that lists the errors that are made
d. A telephone that has buttons to press

49. ____

CONTINUED

50. What does "yogurt" mean in the following sentence?

My sister always eats yogurt for lunch.

a. Some vegetables
b. Some meat
c. A low-calorie milk product
d. A sandwich

50. _____

51. What does "direct benefit payment" mean in the following sentence?

Since he has retired, my grandfather receives a direct benefit payment from the government in the form of a Social Security check.

a. Money received to cover living expenses
b. Tax reduction for working many years
c. A special gift for men only
d. Tax deduction for not working any more

51. _____

52. What does "trend" mean in the following sentence?

If the trend continues, the cost of living will increase again next year.

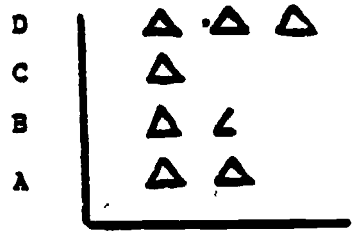
a. Different pattern
b. Time
c. Place
d. Same pattern

52. _____

ERIC

PART ___. GRAPHICAL FORM

Use the following picture to answer questions 1 through 3:



1. Which is the smallest quantity?

   a. A c. C
   b. B d. D

   1. ____

2. Which is the largest quantity?

   a. A c. C
   b. B d. D

   2. ____

3. Which represents an amount of zero?

   a. A c. C
   b. B d. None

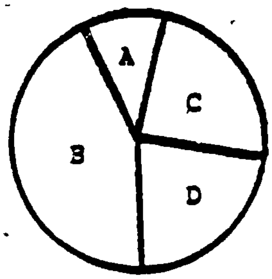
   3. ____

4. For what is a circle used?

   a. To show length and width
   b. To show height
   c. To show the parts of one whole
   d. To show volume

   4. ____

Use the following picture to answer questions 5 through 7:



5. Which portion in the above picture is the largest?

   a. A c. C
   b. B d. D

   5. ____

6. Which portion in the above picture is the smallest?

   a. A c. C
   b. B d. D

   6. ____

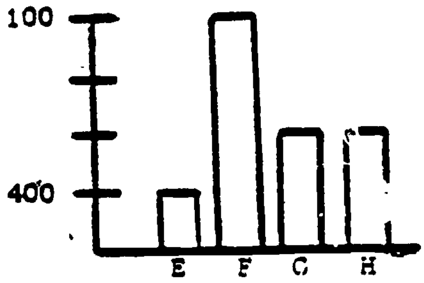
7. Which portions in the above picture seem to represent the same amount?

   a. A and C c. C and D
   b. B and D d. A and B

   7. ____

CONTINUED

Use the following picture to answer questions 8 and 9:



8. Which represents the largest quantity?

   a. E c. G
   b. F d. H

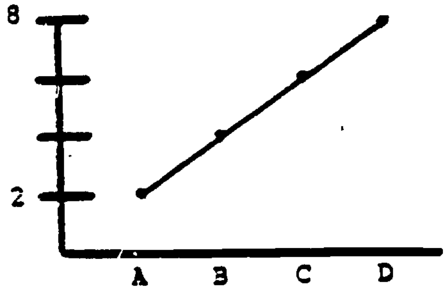
8. ____

9. Which represents the smallest quantity?

   a. E c. G
   b. F d. H

9. ____

Use the following picture to answer questions 10 through 17:



10. What does this picture represent?

    a. An increase
    b. A decrease
    c. Remains the same
    d. Increases and then decreases

10. ____

11. Which represents the largest quantity?

    a. A c. C
    b. B d. D

11. ____

12. Which represents the smallest quantity?

    a. A c. C
    b. B d. D

12. ____

13. How much does each interval represent?

    a. One c. Four
    b. Two d. Eight

13. ____

14. What is the value of C?

    a. 2 c. 6
    b. 4 d. 8

14. ____

15. Which quantity has a measure of 4?

    a. A c. C
    b. B d. D

15. ____

16. Which quantity has a measure of 8?

    a. A c. C
    b. B d. D

16. ____

CONTINUED

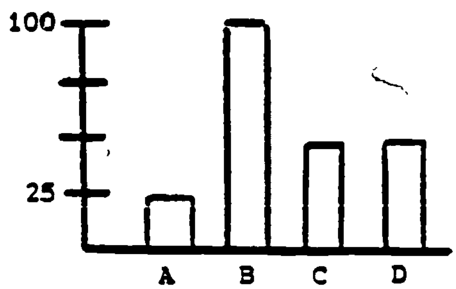
Question 17 refers to the picture for questions 10 through 17 on the previous page:

17. When is a picture like this used?

a. To show the parts of one whole
b. To compare continuous information
c. To compare information that is not continuous
d. To show shapes of figures

17. _____

Use the following picture to answer questions 18 through 24:



18. Which two items represent the same amount?

a. A and B   c. C and D
b. B and C   d. D and A

18. _____

19. What amount does C represent?

a. 0   c. 100
b. 50   d. 125

19. _____

20. Which represents the largest quantity?

a. A   c. C
b. B   d. D

20. _____

21. Which represents the smallest quantity?

a. A   c. C
b. B   d. D

21. _____

22. Which quantity has a measure of 100?

a. A   c. C
b. B   d. D

22. _____

23. Which quantity has a measure of 25?

a. A   c. C
b. B   d. D

23. _____

24. When is a picture like this used?

a. To show the parts of one whole
b. To compare different amounts
c. To show a straight line
d. To compare continuous information

24. _____

CONTINUED

Use the following picture to answer questions 25 through 27:

▲ = 10 triangles

25. What does the above picture mean?

    a. Ten triangles represent three triangles
    b. One triangle represents one triangle
    c. Three triangles represent ten triangles
    d. One triangle represents ten triangles

25. _____

26. What would ▲ ▲ represent?

    a. Two triangles
    b. Five triangles
    c. Ten triangles
    d. Twenty triangles

26. _____

27. What would ◭ represent?

    a. One-half of a triangle
    b. Five triangles
    c. Ten triangles
    d. Twenty triangles

27. _____

Prior Knowledge Inventory Answer Key

Mathematical Content

1.	c	10.	b	20.	b	32.	b	43.	d	54.	c
2.	d	11.	c	21.	c	33.	c	44.	a	55.	d
3.	a	12.	b	22.	d	34.	b	45.	c	56.	c
4.	d	13.	b	23.	c	35.	d	46.	a	57.	b
5.	c	14.	b	24.	b	36.	b	47.	c	58.	c
6.	d	15.	d	25.	a	37.	a	48.	c	59.	c
7.	a	16.	c	26.	c	38.	b	49.	d	60.	b
8.	d	17.	c	27.	b	39.	d	50.	c	61.	d
9.	c	18.	b	28.	a	40.	c	51.	d	62.	d
		19.	b	29.	c	41.	c	52.	c	63.	b
				30.	d	42.	a	53.	b	64.	d
				31.	c						

Topic

1.	b	5.	b	11.	a	16.	d	22.	d	28.	b	34.	b
2.	c	6.	d	12.	b	17.	b	23.	b	29.	c	35.	b
3.	b	7.	b	13.	b	18.	c	24.	b	30.	b	36.	b
4.	a	8.	a	14.	b	19.	c	25.	d	31.	c	37.	d
		9.	b	15.	b	20.	c	26.	a	32.	d	38.	b
		10.	c			21.	a	27.	c	33.	d		

39.	b	45.	d	50.	c
40.	c	46.	a	51.	a
41.	c	47.	d	52.	d
42.	b	48.	b		
43.	a	49.	a		
44.	a				

Prior Knowledge Inventory Answer Key

Graphical Form

1. c	8. a	17. b	25. d
2. a	9. b	18. c	26. d
3. d	10. a	19. b	27. b
4. c	11. d	20. b	
5. b	12. a	21. a	
6. a	13. b	22. b	
7. c	14. c	23. a	
	15. b	24. b	
	16. d		

Instructions for Administering the Prior Knowledge Inventory

1. Check students' seating arrangement.
2. Each student who has parental consent should receive a pencil and a test booklet. You should have received a roster with this information.
3. For your own information, there are six different forms of the Prior Knowledge Inventory in which the three subtests (Mathematical Content, Topic, and Graphical Form) have been arranged in different order.
4. Read the following italicized instructions aloud to students:

Good morning.

You are being asked to participate in a research study to help determine how children read graphs. Your results will be helping us to help children improve their graph reading skills.

Today is the first of four sessions. The results of the tests will not affect your marks in school, but please try to do your best and answer all of the questions.

Print your first name and your last name in the space provided on the cover sheet. Also, write today's date, which is ______, in the space provided. Read the directions silently as I read them aloud to you:

In sentences A and B, please check the part that applies to you:

A. I am a ___ boy.
___ girl.

If you are a boy, put a check in front of "boy." If you are a girl, put a check on the line in front of "girl."

B. At home, I ___ do NOT speak English. I speak another language.

If you do not speak English at home, but instead speak Spanish, Chinese, French, Greek, Italian, Russian, or another language, put a check on the line.

At home, I ___ speak English AND 1 or more other languages.

If this statement applies to you because you speak English and Spanish, or English and Greek, or English and Chinese, or English and German, or English and Italian, or English and another language, put a check on the line.

At home, I ___ speak ONLY English.

If this statement applies to you, put a check on the line. You should have only one of the three lines in sentence B checked. If you have any questions, please raise your hand.

5. After all questions have been answered, proceed to the next section, reading aloud the following italicized instructions:

This booklet contains three parts: Mathematical Content, Topic, and Graphical Form. Don't worry if you do not understand these titles. Just read each question carefully and THINK before answering.

You may find some questions to be more difficult than others. Try to do your best and answer all of the questions.

DIRECTIONS: For each question, select the letter in front of the choice that best answers the question and place it in the space provided near the question.

Have the following example ready on the chalkboard:

S1. What does "house" mean in the following sentence?

Last week our house was painted.

a. An airplane

b. A place to live

c. A car *S1. b*

The correct choice is b. You would write "b" in the space provided. Your scrap work may be done in the booklet. As you complete each part, go ahead to the next page. You will have 1 hour and 15 minutes to complete this test. If you should finish before time is up, go back and check your work. Thank you for your cooperation and participating in this research study.

Are there any questions?

Open your booklet to the first page, and begin.

6. Keep the time posted on the chalkboard.
7. Inform students when there is ten minutes left; one minute left.

Prior Knowledge Inventory - Administration Instructions - Continued

8. When time is up, read the following aloud to the students:

   Stop work. Pencils down. Close your booklets. Pass your booklet to the _____ (front, left, right).

   Instruct students to pass their booklets to the front or the left or the right, which ever is appropriate or convenient for you.

   Be sure to collect all pencils!

Appendix C

Prior Knowledge Inventory Items Reflecting Graph Test Items

Key for Matching Graph Test Items and Prior Knowledge Inventory Items

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Prior Knowledge Inventory Items Reflecting Graph Test Items

Prior Knowledge Inventory	Graph 1 Items						Graph 2 Items						Graph 3 Items					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Topic Items	16 18	27	16 18	42					38		28		24 40	25 40	25 40	1 17 44	40	24 45 51
Mathematical Content Items			38	33	24	27 38			42	4 29	20 40	4 20 41 45 49			12		11 13	
Graphical Form Items			4						5 6 7	4		4			4			5 6

Prior Knowledge Inventory Items
Reflecting Graph Test Items
(Continued)

Prior Knowledge Inventory	Graph 4 Items						Graph 5 Items						Graph 6 Items					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Topic Items	32, 46	32	20, 32	32	32	22, 32	14	14	14		4, 14	14	21, 30, 47	19, 21	8, 13, 19, 21, 50	8, 19, 21, 50	8, 19, 21, 35, 50	8, 13, 19, 21, 50
Mathematical Content Items		2		2, 23	2, 18, 28, 37					1	6, 7				8, 43	3, 8		19, 22
Graphical Form Items		19	8, 9, 20, 21	24	19		19	22, 23	24	19	19			19	8, 9, 18, 20, 21, 24	8, 9, 18, 21, 24	8, 9, 18, 19, 20, 21	

Prior Knowledge Inventory Items
Reflecting Graph Test Items
(Continued)

Prior Knowledge Inventory	Graph 7 Items						Graph 8 Items						Graph 9 Items					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Topic Items	10 11 49	10 11	10 11 49	10 49	10 11 49	10	6 15	15	15		6 15 23 29 37	6 9 15 26	34 41	34	34	3 34 41	3 12 34	3 12 34
Mathematical Content Items			10	14						17		16	15 36 39	15		48		
'raphical Form Items	14		10 17		11 12 17	17	14	15 16	10 11 12 17	13	17		14	15 16	11 12 14	10	10	10

Prior Knowledge Inventory Items
Reflecting Graph Test Items
(Continued)

Prior Knowledge Inventory	Graph 10 Items						Graph 11 Items						Graph 12 Items					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Topic Items	7																	4
	31				2	7	5	5	5	5	5	5					33	39
	48	31			48	52	36	36	36	36	36	36		43	43	43	43	43
Mathematical Content Items				31														
				32														
				35												5		
				50						34	54	25			47	47	9	
				52						51	58	34			55	55	26	
		21		61	44		56	60	64	57	62	53		55	59	63	36	46
Graphical Form Items																1		
																2		
										25					25	25	25	25
		25	1	1				3	1	26	25	25		25	26	26	26	26
		26	2	2			25	27	2	27	26	26	25	27	27	27	27	27

Key for Matching Graph Test Items and Prior Knowledge Inventory Items

Topic Subtest

Item	Graph, Item	Item	Graph, Item
1	(3,4)	26	(8,6)
2	(10,5)	27	(1,2)
3	(9,4)(9,5)(9,6)	28	(2,5)
4	(5,5)(12,6)	29	(8,5)
5	(11,1)(11,2)(11,3)(11,4) (11,5)(11,6)	30	(6,1)
6	(8,1)(8,5)(8,6)	31	(10,1)(10,2)
7	(10,1)(10,6)	32	(4,1)(4,2)(4,3)(4,4)(4,5)(4,6)
8	(6,3)(6,4)(6,5)(6,6)	33	(12,5)
9	(8,6)	34	(9,1)(9,2)(9,3)(9,4)(9,5)(9,6)
10	(7,1)(7,2)(7,3)(7,4) (7,5)(7,6)	35	(6,5)
11	(7,1)(7,2)(7,3)(7,5)	36	(11,1)(11,2)(11,3)(11,4)(11,5) (11,6)
12	(9,5)(9,6)	37	(8,5)
13	(6,3)(6,6)	38	(2,3)
14	(5,1)(5,2)(5,3)(5,5)(5,6)	39	(12,6)
15	(8,1)(8,2)(8,3)(8,5)(8,6)	40	(3,1)(3,2)(3,3)(3,5)
16	(1,1)(1,3)	41	(9,1)(9,4)
17	(3,4)	42	(1,4)
18	(1,1)(1,3)	43	(12,2)(12,3)(12,4)(12,5)(12,6)
19	(6,2)(6,3)(6,4)(6,5)(6,6)	44	(3,4)
20	(4,3)	45	(3,6)
21	(6,1)(6,2)(6,3)(6,4) (6,5)(6,6)	46	(4,1)
22	(4,6)	47	(6,1)
23	(8,5)	48	(10,1)(10,5)
24	(3,1)(3,6)	49	(7,1)(7,3)(7,4)(7,5)
25	(3,2)(3,3)	50	(6,3)(6,4)(6,5)(6,6)
		51	(3,6)
		52	(10,6)

Key for Matching Graph Test Items and Prior Knowledge Inventory Items

Mathematical Content Subtest

Item	Graph, Item	Item	Graph, Item	Item	Graph, Item
1	(5,4)	22	(6,6)	43	(6,3)
2	(4,2)(4,4)(4,5)	23	(4,4)	44	(10,5)
3	(6,4)	24	(1,5)	45	(2,6)
4	(2,4)(2,6)	25	(11,6)	46	(12,6)
5	(12,4)	26	(12,5)	47	(12,3)(12,4)
6	(5,5)	27	(1,6)	48	(9,4)
7	(5,5)	28	(4,5)	49	(2,6)
8	(6,3)(6,4)	29	(2,4)	50	(10,4)
9	(12,5)	30	(9,1)	51	(11,4)
10	(7,3)	31	(10,4)	52	(10,4)
11	(3,5)	32	(10,4)	53	(11,6)
12	(3,3)	33	(1,4)	54	(11,5)
13	(3,5)	34	(11,4)(11,6)	55	(12,2)(12,3)(12,4)
14	(7,4)	35	(10,4)	56	(11,1)
15	(9,1)(9,2)	36	(12,5)	57	(11,4)
16	(8,6)	37	(4,5)	58	(11,5)
17	(8,4)	38	(1,3)(1,6)	59	(12,3)
18	(4,5)	39	(9,1)	60	(11,2)
19	(6,6)	40	(2,5)	61	(10,4)
20	(2,5)(2,6)	41	(2,6)	62	(11,5)
21	(10,2)	42	(2,3)	63	(12,4)
				64	(11,3)

Key for Matching Graph Test Items and Prior Knowledge Inventory Items

Graphical Form Subtest

Item	Graph, Item
1	(10,3)(10,4)(11,3)(12,4)
2	(10,3)(10,4)(11,3)(12,4)
3	(11,2)
4	(1,3)(2,4)(2,6)(3,3)
5	(2,3)(3,6)
6	(2,3)(3,6)
7	(2,3)
8	(4,3)(6,3)(6,4)(6,5)
9	(4,3)(6,3)(6,4)(6,5)
10	(7,3)(8,3)(9,4)(9,5)(9,6)
11	(7,5)(8,3)(9,3)
12	(7,5)(8,3)(9,3)
13	(8,4)
14	(7,1)(8,1)(9,1)(9,3)
15	(8,2)(9,2)
16	(8,2)(9,2)
17	(7,3)(7,5)(7,6)(8,3)(8,4)
18	(6,3)(6,4)(6,5)
19	(4,2)(4,5)(5,1)(5,4)(5,5)(6,2)(6,5)
20	(4,3)(6,3)(6,5)
21	(4,3)(6,3)(6,4)(6,5)
22	(5,2)
23	(5,2)
24	(4,4)(5,3)(6,3)(6,4)
25	(10,2)(11,1)(11,4)(11,5)(11,6)(12,1)(12,2)(12,3)(12,4)(12,5)(12,6)
26	(10,2)(11,4)(11,5)(11,6)(12,3)(12.4)(12,5)(12,6)
27	(11,2)(11,4)(12,2)(12,3)(12,4)(12,5)(12,6)

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Appendix D

Letters of Approval

Request for Parental Consent

ERIC

New York City
Board of Education

110 Livingston Street
Brooklyn New York 11201

Frank J. Macchiarola
Chancellor of Schools

Alan S. Blumner
Director (Acting)
Office of Educational Evaluation
(212) 596-4045

January 11, 1980

Ms. Frances R. Curcio
Department of Education
St. Francis College
180 Remsen Street
Brooklyn, NY 11201

Dear Ms. Curcio:

I am happy to inform you that your proposed study entitled, "The Effect Of Reading And Math Achievement, Race Status, Sex And Prior Knowledge On Comprehending Mathematical Relationships Expressed In Graphs", has been approved by the Office of Educational Evaluation with the following conditions:

1. Before involving any child in your study, you must obtain written parental consent. (I have enclosed a form which you may follow in drawing up your own <u>Parental Permission Form</u>.)
2. Your report of the study should not include identification of any school or school personnel. A code system should be used.
3. You must make it very clear to your prospective respondents that their cooperation is on a purely voluntary basis.

Whenever your report is ready, I would be interested in receiving a copy. Best wishes in this endeavor.

Sincerely,

Alan S. Blumner
Director (Acting)

ASB/ch
enclosures

P.S. You may duplicate this letter in any quantity you need in order to inform cooperating principals and community superintendents that you have received approval form the Office of Educational Evaluation.

CITY OF NEW YORK
BOARD OF EDUCATION
OFFICE OF SCHOOL DISTRICT 20

1031 - 59TH STREET
BROOKLYN, NEW YORK 11219

TEL. 851-3200

DENIS M. FLEMING
COMMUNITY SUPERINTENDENT

Lucretia Marcigliano
PRESIDENT CSB

January 17, 1980

Ms. Frances R. Curcio
Department of Education
St. Francis College
180 Ramsen Street
Brooklyn, New York 11201

Dear Ms. Curcio:

You have my permission to conduct your research study within District 20.

Good luck in your endeavor.

Very truly yours,

DENIS M. FLEMING
Community Superintendent

DMF:jl

ERIC

St. Francis College
180 Remsen Street
Brooklyn, N. Y. 11201
Department of Education
212 : 522-2300

September, 1980

Dear Parents:

Your child ____________________ of class _____ has been selected to participate in a federally funded testing program, scheduled to take place this Fall. The purpose of this program is to discover how graph reading ability can be assessed and, ultimately, improved. Since the ability to read a graph is a basic skill required for literacy, a graph test has been designed to reflect different tasks of comprehension.

The graph test, reading test and mathematics test will be presented to your child during class time and will be administered during four different testing sessions (each lasting approximately one hour).

I am requesting your permission to present the graph exercises and achievement tests to your child and ask him/her how he/she answered the questions pertaining to the graph. The results of the tests will include NO identifying device, signature or number so that the confidentiality of your child's reply will be completely secure.

Please sign the statement of consent below and have your child return it to his/her teacher tomorrow. If you have any questions, please feel free to contact me at JA2-2300, x 282.

Thank you for your cooperation and interest in helping children develop basic skills.

Sincerely,

Frances R. Curcio
Project Director

APPROVED: DENIS M. FLEMING
District 20, Community Superintendent

. . . .

Dear Miss Curcio:

I give my child ____________________ of class _____ permission to participate in the federally funded testing program. I understand that the purpose of this program is to discover how graph reading ability can be assessed and, ultimately, improved.

________________ Date

________________ Parent's Signature

Appendix E

Zero-Order Partial Correlation Matrix for
Fourth-Grade Girls and Boys

Zero-Order Partial Correlation Matrix for
Seventh-Grade Girls and Boys

First-Order Partial Correlations of
Graph Comprehension Results of Fourth-Grade Girls and Boys
with Reading and Mathematics Achievement

First-Order Partial Correlations of
Graph Comprehension Results of Seventh-Grade Girls and Boys
with Reading and Mathematics Achievement

Second-Order Partial Correlation Matrix for
Fourth-Grade Girls and Boys

Second-Order Partial Correlation Matrix for
Seventh-Grade Girls and Boys

Table E1

Zero-Order Partial Correlation Matrix for
Fourth-Grade Girls and Boys

Variables	Topic	Mathematical Content	Graphical Form	Reading Achievement	Mathematics Achievement	Graph Comprehension
Topic		.51	.52	.60	.62	.65
Mathematical Content	*.25*		.58	.52	.65	.70
Graphical Form	*.54*	*.42*		.62	.62	.64
Reading Achievement	*.71*	*.35*	*.58*		.61	.67
Mathematics Achievement	*.51*	*.42*	*.56*	*.56*		.70
Graph Comprehension	*.61*	*.55*	*.62*	*.73*	*.65*	

Note. The entries above the diagonal are the correlations for the fourth-grade girls. The italicized entries below the diagonal are the correlations for the fourth-grade boys. All correlations are significant at $p < .001$.

Table E2

Zero-Order Partial Correlation Matrix for Seventh-Grade Girls and Boys

Variables	Topic	Mathematical Content	Graphical Form	Reading Achievement	Mathematics Achievement	Graph Comprehension
Topic		.54	.47	.65	.46	.60
Mathematical Content	*.55*		.41	.59	.67	.73
Graphical Form	*.46*	*.38*		.56	.49	.49
Reading Achievement	*.72*	*.43*	*.41*		.68	.67
Mathematics Achievement	*.45*	*.59*	*.35*	*.50*		70
Graph Comprehension	*.55*	*.59*	*.41*	*.69*	*.67*	

Note. The entries above the diagonal are the correlations for the seventh-grade girls. The italicized entries below the diagonal are the correlations for the seventh-grade boys. All correlations are significant at $p < .001$.

Table E3

First-Order Partial Correlations of
Graph Comprehension Results of Fourth-Grade Girls and Boys
with Reading and Mathematics Achievement
Controlling for Mathematics and Reading Achievement, Respectively

Variable	Graph Comprehension: Girls	Graph Comprehension: Boys	Control Variable
Reading Achievement	.42*	.58*	Mathematics Achievement
Mathematics Achievement	.50*	.43*	Reading Achievement

*$p < .001$.

Table E4

First-Order Partial Correlations of
Graph Comprehension Results of Seventh-Grade Girls and Boys
with Reading and Mathematics Achievement
Controlling for Mathematics and Reading Achievement, Respectively

Variable	Graph Comprehension: Girls	Graph Comprehension: Boys	Control Variable
Reading Achievement	.37*	.55*	Mathematics Achievement
Mathematics Achievement	.46*	.52*	Reading Achievement

*$p < .001$.

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Table E5

Second-Order Partial Correlation Matrix for
Fourth-Grade Girls and Boys
Controlling for Reading Achievement and Mathematics Achievement

Variables	Topic	Mathematical Content	Graphical Form	Graph Comprehension
Topic		.12	.11	.29**
Mathematical Content	- *.05*		.25*	.41**
Graphical Form	*.18*	*.20**		.26**
Graph Comprehension	*.14*	*.38***	*.22***	

Note. The entries above the diagonal are the second-order correlations for the fourth-grade girls. The italicized entries below the diagonal are the second-order correlations for the fourth-grade boys.

*$p < .05$.

**$p < .01$.

Table E6

Second-Order Partial Correlation Matrix for
Seventh-Grade Girls and Boys
Controlling for Reading Achievement and Mathematics Achievement

Variables	Topic	Mathematical Content	Graphical Form	Graph Comprehension
Topic		.26*	.17	.31**
Mathematical Content	*.35***		.04	.45**
Graphical Form	*.24**	*.19*		.13
Graph Comprehension	*.04*	*.27***	*.12*	

Note. The entries above the diagonal are the second-order correlations for the seventh-grade girls. The italicized entries below the diagonal are the second-order correlations for the seventh-grade boys.

*$p < .05$.

**$p < .01$.

Appendix F

AN EXPLORATORY, DESCRIPTIVE ANALYSIS OF PROCESSING INFORMATION PRESENTED IN GRAPHICAL FORM

Compiled and Written with the Assistance of
Dr. M. Trika Smith-Burke

ERIC

AN EXPLORATORY, DESCRIPTIVE ANALYSIS OF PROCESSING INFORMATION PRESENTED IN GRAPHICAL FORM

Introduction

The ideas, rationale, and objectives for this exploratory, descriptive study developed from the results of the experimental study presented and discussed in Chapters 4 and 5. The method employed in the dissertation was designed to explore the effect of prior knowledge on graph comprehension which 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 students were able to comprehend the mathematical relationships expressed in the graphs. It was thought that how prior knowledge affects graph comprehension might be somewhat revealed by asking children to respond to graph items requiring them to "think aloud." In this way, the "process" of comprehension, highlighting some of the strategies that might be employed by children trying to determine the "meaning" of the graph, might be revealed.

Rationale

The graph test designed for the experimental study (see Appendix A) was composed of twelve graphs each containing six questions reflecting three levels of comprehension. Two questions were "task a" items (requiring a literal reading of the data, title, or axes' labels); two questions were "task b" items (requiring comparisons and the use of mathematical concepts and skills to read "between the data"); and two questions were "task c" items (requiring an extension, prediction, or inference dependent upon prior knowledge to read "beyond the data"). Similar to comprehending general discourse, it is important to explore whether certain tasks are confronted by individuals from a text-base (bottom-up processing), schema-base (top-down processing), or a combination of both (Spiro, 1980, Note 1). Since the results of the experimental study seem to indicate that for different grade levels, different aspects of prior knowledge affect graph comprehension, the descriptive data collected in this small-scale study might add a new dimension to the statistical analysis. Allowing individual children to comment, react, and discuss their answers to selected graph tasks might contribute to our limited understanding of graph comprehension.

Janvier (1978) recognized the difficulty of assessing the influence of relevant prior knowledge on graph comprehension. However, interviewing the adolescents in his sample did enable him to categorize responses and formulate hypotheses. His work has provided some foundation upon which this small-scale investigation was based.

Objectives

A supplemental, descriptive analysis was conducted ex post facto. The purpose of this additional exploratory work was to:

1. Examine how children process different tasks of comprehension;

2. Identify how prior knowledge affects graph comprehension and the strategies employed to bring that knowledge to bear;

3. Obtain students' reactions and suggestions for improving aspects of the graphs and questions which might be confusing;

4. Relate descriptive data collected to the results of the previous study;

5. Develop and refine interview protocol and probing techniques;

6. Generate research questions.

The Sample

Eight fourth graders (3 girls and 5 boys) and 9 seventh graders (5 girls and 4 boys) who participated in the original 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 F1 for a list of the students' reading and mathematics achievement profiles.

Procedure

The interviews were conducted by three individuals who were prepared to follow the interview protocol (see Figure F1). Two ot 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

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TABLE F1

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.

Interview Protocol[1]

The interview protocol, reflecting the objectives of this exploratory work, was as follows:

Get students' birthdate and/or age and first name.

A few months ago you took some math tests. The reason why you took these tests is that we are trying to learn how students understand and solve math problems.

What I'd like to do today is ask you some questions about the math questions from the test. What I'd like you to do is to tell me how you understood the problem, how you figured out which answer to choose, and why you did not choose the other possible answers. If you found something confusing or you did not understand something in a problem, this is <u>*just*</u> *as important to tell me as telling me about what you understood completely. We really need your help to design better materials for students. O.K., let's start.*

1. *First, here are four problems from the test* (displaying four different graph-types, without questions). *What are these drawings called?* (Try to elicit specific types of graphs.)

2. *Can you tell me where you might see these graphs?* (If student says, "textbooks," probe for <u>real life</u> contexts as well as asking what kind of texts.)
   a. *What kind of texts?*
   b. *Can you think of any other places you might see these that don't have to do with school?*

   or

   Can you think of any materials other than texts that these graphs appear in?

3. *Why do you think graphs are used in these materials? Why would someone use a graph to describe a situation?*

4. *There are four different kinds of graphs here. Why do you think someone making a graph might use one kind of graph over another?*
   Are there different reasons for choosing to use one kind of graph over another?
   What kind of information is usually represented in a bar graph? Circle graph? Line graph? Pictograph?

5. *Could you describe an easier way to represent the information in a graph?*

Before showing graphs, ask fourth graders questions 6-9, ask seventh graders questions 8-11:

6. *If you were a stamp collector, why would you collect stamps? How does collecting stamps relate to the value of the stamp? What makes the value of a stamp increase?*

7. *How do you spend your day? What kind of activities do you do? Which activity takes the most time? Least time? Which do you like best? During school? After school?*

8. *When is sunset? Sunrise?* (Make sure to elicit A.M./P.M., morning, afternoon, evening.) *How long are the days in the winter compared with days in the summer? Could you tell me why this is so?*

9. *How tall are you (approximately)? What other scale can you be measured in? Do you have any brothers or sisters? Older? Younger? How does you height compare with your brother's/sister's?*

10. *Have you ever heard of "Gross National Product"? Where have you heard this term? What do you think it means? Do you know what a recession is? Where have you heard this term before?*

11. *Do you know how the U.S. Government spends its money? What kinds of things is the money spend for? Are there certain items that require more money than other items? How is this determined?*

Scanning

12. *O.K., let's look at the first graph. First I'd like you to tell me what you know from just looking at the graph.* (Probe for title and axes.)

13. *Now what I'd like to do is go over each question. Please tell me what you are thinking and how and why you chose your answer. Remember, if something is confusing, please tell me why it's confusing and what you did with this when you tried to answer the questions.*

14. *Now tell me why you didn't choose ______?* (Probing)

15. *Is there anything about this graph or the questions that you think might be confusing for fourth/seventh graders?*

[1] Written with the assistance of Dr. M. Trika Smith-Burke.

Figure F1.

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that the tape recorder, which was within view, was being used to help remember all the suggestions that the child made. 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 asked, and in some cases the child was corrected for misconceptions.

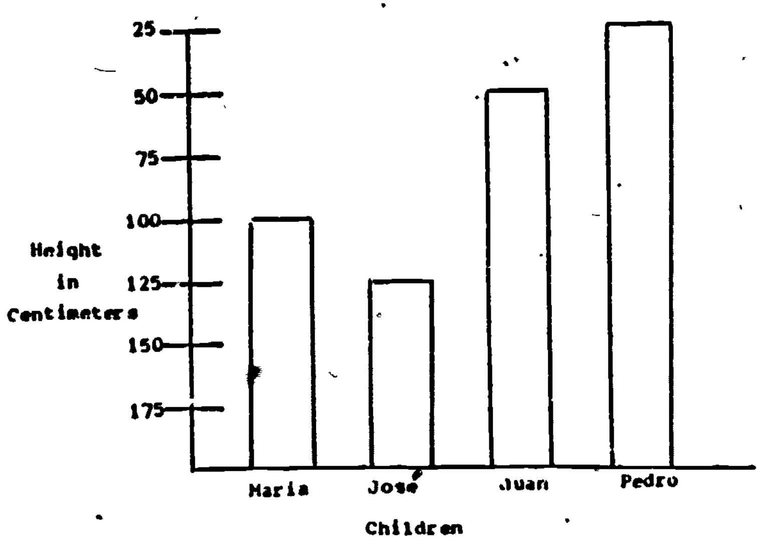
All the students were questioned about Graph 8: Average Time of Sunset (see Appendix A, page 118), and a revision of Graph 4: Height of the Rodriguez Children in March, 1980 (see Figure F2). This revision was made because it was interesting to observe students' reactions to a format contrary to their 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. For the interviews, item 6 was used in the following, original form:

"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."

It was recognized that a revision of this item was necessary because the original form of item 6 has more than one "correct" answer (a and b). Therefore, item 6 is revised for future use in Figure F2.

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 María?
   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. María

3. ___

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

4. ___

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

6. ___

Figure F2.

Four fourth graders were questioned about Graph 2: How Terry Spends a School Day (see Appendix A, page 112), and four fourth graders were questioned about Graph 12: Stamps Collected by Children (see Appendix A, page 122). Five seventh graders were questioned about Graph 9: The Gross National Product During 1969 Through 1979 (see Appendix A, page 119), four seventh graders were questioned about Graph 3: The U.S. Government's 1981 Dollar Budget (see Appendix A, page 113), and one seventh grader was questioned about Graph 2: How Terry Spends a School Day (see Appendix A, page 112). 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. Also the amount of time did not warrant the use of all twelve graphs.

Criteria for Inferences

The interviews revealed that the children approached different tasks of comprehension differently. As a result, in order to identify the processes of comprehension and analyze the responses, the following categories were identified and criteria for classification and evaluation were assigned:

1. *Text-Based* (also termed bottom-up processing). 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

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was implicit; i.e., the children knew how to locate specific coordinates or refer to the axes' labels.)

2. *Schema-Based* (also termed top-down processing). Responses of the children who relied upon their background knowledge when responding to graph questions can be classified into the following categories:

a. *Not attending to the graph.* 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]."

b. *Attends to the graph but is distracted by the topic.* In this case, the children were overly concerned with the topic of the graph to such a great extent that their descriptions and explanations go off on a tangent; i.e., the discussion is somewhat related to the graph [illegible] children are sidetracked by "pouring out" their prior knowledge about the topic.

c. *Attends to the graph but does not recognize inconsistencies.* 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.

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

Results and Discussion

It is important to mention that this supplementary data is exploratory in nature and that these results are to be reviewed with caution.

Text-Based Comprehension Processing

All the children, except one (S79), answered the task a questions by referring to the text. Not all children, however, were adept at reading the data directly from the graph. In some cases, fourth graders had trouble with Graph 8, matching the months on the horizontal axis with the average time of sunset on the vertical axis. Perhaps horizontal and vertical lines should be used (similar to graph paper) for younger children to help guide them in locating coordinate pairs on a line graph.

The following examples reflect text-based comprehension processing:

Example 1. Referring to Graph 8, Item 2.

I[1]: *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.*

Example 2. Referring to Graph 8, Item 2.

I: *Let's look at number 2.*
S42: (silent reading) *November?*
I: *And, how did you get that answer?*
S42: *Because this thing goes right across here and it's right on top, it looks on top of November* (showing on the graph).

Example 3. Referring to Graph 12, Item 1.

I: (reading item #1) *What does each symbol, like this, represent? O.K., now can you tell me how you figured out which*

---

[1] I = interviewer.

answer you chose and how you figured it out? Take your time.
S41: *Well, I looked at the symbol and I then looked at that thing* (pointing to the key), *right? and I saw it was four stamps, and I picked c.*

The above three examples represent typical responses to task a items. (Task a items were the first two questions for each graph.) Since task a items require a literal reading of the graph, it seems as though students enact text-based processing strategies for this type of comprehension. In general, students who employ text-based processing strategies for task b or task c items usually do not have enough information to respond to the questions successfully. Examples 4 and 5 highlight this problem.

Example 4. Referring to Graph 2, 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.*

Example 5. Referring to Graph 8, Item 5.
I: (reading item #5) *Which of the following graphs represents the average time of sunset in January to June that will make the above graph represent one complete year?*
S77: (long silence) *I think that one.*
I: *Which one is that? What letter?*
S77: *a.*
I: *Why did you chose a?*
S77: *It's curvey like* (pointing to the graph)
I: *It's the same curve as the other one?* (referring to the main graph)
S77: *Yeah.*

In Example 4, 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). It is possible that S47 did not

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did not remember that the circle graph represented the time spent during *one* day, since reference is made to "a week." However, during the preliminary discussion about the graph, the student did recognize that the activities and time for each was during one day.

In Example 5, S77 concentrated on the graph without considering what was being asked and bringing forth any prior knowledge that might have been relevant to what was asked. Some prior knowledge related to this topic was identified throughout the interview because after probing, S77 answered items 3, 4, and 6 correctly.

In both cases, the students' limited information (obtained solely from the text) was inadequate in processing tasks of comprehension designed to tap their prior knowledge. A question for future research is "How can we help students recognize when the answer is solely in the text, and when the text itself is inadequate?"

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; attending 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. Some children had such a rich knowledge base that the information in the graph was superfluous and not needed to answer some of the task b and task c items. (For every graph, task b items were the third and fourth questions, and task c items were the last two questions.)

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 responses. 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.

The following examples highlight this schema-based processing approach:

Example 6. Referring to Graph 8, 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...*

Example 7. Referring to Graph 8, Item 3.

I: *All right. Number three.* (reading item #3) *As the months progressed from June to December, which of the following is true about the average time of sunset?*
S48: (long pause) *Sometimes it gets earlier.*
I: *Can you explain to me how you figured that out?*
S42: *Well, . . . you have to set the clock back one hour.*
I: *And, what does that tell you about?*
S42: *Well, you set your clock back from 2·00 to 1:00 then that's earlier.*
I: *I see. And how does that relate to sunset?*
S48: *I don't know.*
I: *That's an interesting question, isn't it? Let's look at the graph here and see if you can tell me how you figured out the answer you got. You said that as the months progressed from June to December which of the following is true about the average time of sunset and you said it gets earlier. O.K. How would you know that from the graph?*
S48: *I didn't use the graph.*

Example 8. Referring to Graph 8, 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 Examples 6 and 7, the students answered the items correctly by relying upon their prior knowledge of the topic. In Example 8, where lifting relevant information from the graph (e.g., specific times) and computing the answer was required, the student was not successful. It might be possible that in general, fourth graders are unable to distinguish between their 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. Some children had to rely upon concrete or situational experiences when attempting the tasks. By approaching the task 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. Examples 9 and 10 highlight this point.

Example 9. Referring to Graph 3, Item 6.

I: *Number six.* (reading item #6) *According to the projected 1981 budget, which of the following appears to be correct?* (reading the choices) *There is a greater need to support military defense than direct payments for individuals; There is a greater need to support military defense than aiding states and localities; There is greater need to support foreign., what's that funny word?*
S71: *Commitments*
I: *Commitments than military defense. You know that word then?*
S71: *Yeah.*
I: *Right. There is a greater need to support foreign commitments than direct payments for individuals. Which one-*
S71: *b*
I: *Would you pick? And can you give me a reason why?*
S71: *'Cause you have to support the military, I don't know.*
I: *What were you going to say first. Tell me what you were thinking.*
S71: *I thought that it was for the states, money for the states, and localities.*
I: *O.K., so you changed your mind.*
S71: *Yeah.*

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I: *All right. So you decided that there wasn't a greater need to support the military defense than states and localities. Which one are you going to choose now if you don't choose that one?*
S71: *d*
I: *O.K., why do you think that?*
S71: *'Cause like if they take a little bit of money out of some individuals they could help bring out all the poverty and all, in all the other foreign countries.*

Example 10. Referring to Graph 8, 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.*
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 both of the examples above (and in other responses), it seemed that the children's concerns with the topics distracted them from attending to the deep structure of the graph, which was required in answering the items. In Example 9, S71's attitude towards the situation became evident and dominated his thinking. In Example 10, S48 compared the curve in choice a of item 5 to a sunset. This child related what he has seen, to a picture that he thought represented what he has experienced. These examples seem to agree with Janvier's (1978) observations that for concrete thinkers, the attention is drawn to the situation and the graph completely vanishes (10.5).

Attending to the graph but inconsistencies are not recognized. Some children (8 who had low mathematics achievement scores) did not recognize inconsistencies on the Graph 4 revision (i.e., that the higher the bar, the taller the person who is being represented). This is highlighted in Example 11.

Example 11. Referring to the revision of Graph 4, 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, c 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). This is highlighted in Example 12.

Example 12. Referring to the revision of Graph 4, 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 young children (e.g., fourth graders) are not as flexible in accomodating incoming information that might be inconsistent or contrary to what they expect, 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.

Text-/Schema-Based Comprehension Processing

Task b and task c items were designed to employ prior knowledge as well as referring to the information and data located in the graph. The results of the experimental study 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 three examples.

Example 13. Referring to Graph 3, Item 3.

I: *O.K., number three.* (reading item #3) *What fractional part of each dollar did the U.S. Government spend on net interest?*

S77: *One-eighth* (pause) *no wait* (long pause) *nine-over-a-hundred, b.*

I: *O.K., what did you do right after I read the question. Tell me everything that happened before you decided it was b.*

S77: *I looked for one that had 9 and was broken into a hundred dollars, into pennies equals one hundred.*

I: *But why isn't it c, one-hundred-over-nine?*

S77: *Because then it would be* (pause) *we had to divide nine into one hundred.*

I: *O.K., you said you were looking for nine. Why isn't it a?*
S77: *Because there aren't nine pieces.*
I: *There aren't nine pieces. O.K., first you looked for a nine in the responses, and every one has nines in them. And then after you found out they all had nines in them, what did you do?*
S77: *I looked for a hundred or a dollar.*

Example 14. Referring to Graph 2, Item 5.

I: (reading item #5) *How many hours a week not including Saturday and Sunday did Terry spend on homework?*
S45: (pause) *Ten hours, c?*
How did you figure out it was ten hours?
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 --*
So one day, two hours, two days four hours, three days, six hours, and four days, eight hours, and five days is 10 hours.

Example 15. Referring to Graph 2, 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 your'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 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 on 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 examples, students' 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. In this case 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 becomes 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 3).

Students' Reactions and Suggestions

Students were very helpful in offering suggestions for improving graphs and questions as well as expressing what they thought might be important for their peers when reading some of the graphs. Suggestions for improving the graphs included making some of the dots (within the graphic display of the line graphs) larger and extending horizontal and vertical lines to facilitate locating points. For Graphs 3, 8, and 9, some seventh graders indicated that the vocabulary (e.g., "grants to states," "average ," and "recession") was difficult. For Graph 12, some fourth graders thought that using half of a symbol might be confusing for their peers. For the revision of Graph 4, students (both fourth and seventh graders) suggested that the numbers along the vertical axis be arranged from smallest (at the bottom) to highest (at the top) to conform with their concept of height.

Some students (both fourth and seventh graders) recognized the importance of having knowledge of the topic of the graph, the mathematical content employed in the graph, and the graphical form. The following are examples of their comments.

Example 16. Referring to Graph 9.

I: *Do you think that there is some information that students should know before they are given the graph?*
S72: (pause) *Yeah.*
I: *Could you help me by telling me what information they should know?*
S72: *What the Gross National Product is.*
I: *So it would be helpful if they had a knowledge of what --*
S72: *Yeah, they knew what it was.*
I: *What would that help them do then, if they knew what Gross National Product was?*
S72: *I don't know, it could, um, help know what they're talking about.*
I: *Uh huh. Do you think it might make them interested in trying to figure out what the graph is about if they knew?*
S72: *Yeah, what it's about.*

Example 17. Referring to Graph 2.

I: *Were there any items, anything in any of these questions, that you think someone in fourth grade would have trouble with? Which would you think people in the fourth grade would have trouble doing?*

S44: *If they didn't know fractions they would probably have trouble on what fractional part does, or fraction of a week does she sleep.*

Example 18. Referring to Graph 8.

I: *Do you find any of these questions hard? Would they be hard for fourth graders?*

S42: (nodding no) *Not if they're smart.*

I: *O.K., and, is there anything about the graph that could be improved, is there anything I could do to the graph that would improve it? Can you make any suggestions for me?*

S42: (long pause) *I think it might be easier to put it in a bar graph.*

I: *Oh, you're more familiar with the bar graph or with a line graph?*

S42: *Bar graph.*

I: *And so it would be easier then for all fourth graders, do you think, if this were presented in a bar graph form?*

S42: (nodding in agreement)

I: *Do you think any information can be put into a bar graph?*

S42: *Not all information, but some.*

I: *Could you give me an example of something that couldn't be put in a bar graph?*

S42: (long pause) *Fractions can't be put in a bar graph.*

I: *Oh, so what kind of graph would we use for fractions?*

S42: (pause) *I think that circle graph.*

Interview Protocol Additions and Revisions

As a result of reviewing the tapes of the interviews, the following additions and revisions should be made for the Interview Protocol found on page 17 :

1. Interviews should be conducted in two parts. The first part should include prior knowledge questions (reflecting the topic, mathematical content and graphical form of the graphs to be used) and about two weeks later, present the children with the selected graphs

and accompanying questions. It is possible that asking the prior knowledge questions immediately before presenting the graph tasks to the children might have influenced their responses.

2. The interviewer should read items and distractors aloud as the subjects follow along silently.

3. Avoid indicating whether a response is correct or incorrect.

4. Probe for correct as well as incorrect answers, i.e., ask, "How did you get that answer?" for both correct and incorrect responses.

5. Include the question "What suggestions would you make to improve this graph or some of the questions?"

Questions for Future Research

As a result of this small-scale study, some questions have been generated for future research:

1. How do students determine when to employ text-based comprehension strategies, schema-based comprehension strategies, or a combination/integration of both?

2. With respect to graph reading, is the strategy employed a function of reading achievement, mathematics achievement, prior knowledge, or an interaction of any of these?

3. How do novices (e.g., fourth graders) monitor graph comprehension?

4. How do older students (e.g., seventh graders) monitor graph comprehension?

Reference Notes

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Spiro, R. J. Constructive processes in prose comprehension and recall. In R. J. Spiro, B. C. Bruce, & W. F. Brewer (Eds.), *Theoretical issues in reading comprehension.* Hillsdale, N.J.: Lawrence Erlbaum Associates, Inc., 1980.