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AUTHOR Kaplan, Rochelle G.
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ABSTRACT

Mathematical concepts presented within disciplines outside mathematics are either assumed to be already familiar to the students, or else, they are regarded as being peripheral to the appreciation of the content of the nonmathematical lesson. Because it is routinely included without regard for possible students' interpretations, the mathematical information may actually contribute to students' misconceptions rather than the students' enrichment in both the mathematics and the other discipline. Directly related to this situation is the national concern about geographical illiteracy among students, particularly with respect to its origins within the classroom setting. A study postulated that students' levels of conception (or misconception) in mathematics are associated with the extent of their accuracy in interpreting geographic problems and that particular forms of mathematical competence are highly associated with geographic knowledge. After the collection of representative text materials for grades 3-6, interview protocols consisting of "matching" mathematics and geography tasks were prepared for 64 students (8 boys and 8 girls from each grade) from two schools in a middle-class suburban public school district in northern New Jersey. Results of quantitatively scored interviews indicated a significant positive correlation on overall performance between mathematics tasks and geography tasks. However, although both computational skills and conceptual understanding contributed significantly to this correlation, there was a trend for the relationship between computation and geography performance to decrease in the higher grades, whereas the relationship between conceptual understanding in mathematics and geography performance tended to increase with grade level. (JJK)

The Relationship of Children's Mathematical Knowledge to Their Understanding of Geographical Concepts

Rochelle G. Kaplan
William Paterson College
Wayne, New Jersey

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Relationship of Math
and Geography Knowledge

Rochelle G. Kaplan
William Paterson College

This study examined the relationship between elementary students' knowledge of mathematics concepts and procedures and their ability to understand and interpret geography content in which these concepts and procedures were embedded. The research was motivated by two main concerns, the recommendation of the National Council of Teachers of Mathematics (NCTM) to study mathematics in the context of other curricular areas (1989) and the report of the National Geographic Society about Americans' geographical illiteracy (1988). Each of these concerns is briefly addressed below.

One of the many educational practices recommended in the standards produced by the National Council of Teachers of Mathematics is that students experience using mathematics as part of the content of other curricular areas. In fact, mathematics often is routinely included in textbooks and materials from other disciplines (such as science and social studies), but is not made the explicit focus of instruction. Rather, mathematical concepts are implicitly woven into the text material and used only to complement or highlight aspects of the other discipline. As such, the mathematics presented is either assumed to be familiar to students or else is regarded as peripheral to the appreciation of the content of the non-mathematics material. The mathematical information, then, because it is interspersed without regard for the ways in which it will be interpreted, may contribute to students' misconceptions rather than enriched understanding of both mathematics and the other discipline.

Related to this outcome is the second concern mentioned, that of geographical illiteracy in Americans. The need for concern was prompted by the results of an international survey done by the National Geographic Society (1988) comparing geographical knowledge of contemporary American adults to adults in other industrialized societies and to Americans of 40 years ago. The survey revealed that today's Americans, and particularly today's younger Americans, are seriously lacking in basic geographic knowledge and skills. No doubt we have all heard reports of college students and adults who were unable to identify the United States on a map of the world, who could not identify even one of 16 places on a world map, and who bestow NATO membership on the Soviet Union. At the most obvious level, we might assume that the main reason for these and other types of geographical illiteracy is that Americans simply do not spend very much time studying geography in elementary or secondary schools. Currently there are moves underway to correct this deficiency and, in fact, within the next year or two many states will be mandating the inclusion of some kind of "global" curricular course as a requirement for high school graduation (Daniels, 1988).

There is, however, another way to view the problem of geographical illiteracy and it is that way, in part, that prompted the research reported here. I am referring to attributing the difficulty, not to the amount of time spent on geographical content, but to the appropriateness of the geographical concepts that students are expected to learn. Appropriateness in this context means that the learner has developed the necessary cognitive framework into which the geographical material will fit. This view grows out of a developmental perspective of education suggesting that students will construct different personal meanings from the same objective content depending upon the knowledge and understanding they bring to a task

(Ginsburg, 1989; Piaget, 1929; Piaget and Inhelder, 1969). If there is a mismatch, then, between the information provided and the student's ability to interpret that information in the manner intended by the curriculum developers, that information may be misunderstood and recalled inaccurately. At best it will be learned by rote, recalled accurately over the shortrun, and soon forgotten.

One factor contributing to the problem of geograpical illiteracy, then, may be that educators have failed to view the acquisition of geographical concepts in the context of students' existing knowledge of other academic fields (Adler, 1989; Blaut & Stea, 1971; Downs, Liben, & Daggs, 1988). In particular, the field of mathematics seems to be closely linked to geographical concepts. It appears regularly in social studies texts in terms of map reading and, in general, is sed to represent a wide range of geographical facts and relationships including population, climate, and economics data. Therefore, students may actually be confused about geography, in part, because they are distorting geography text information to conform to their own levels of understanding of mathematical concepts and procedures.

The purpose of this study was to explore this possibility through an examination of the relationship between students' competence in mathematics and their appreciation of geography text material containing mathematical information. It was hypothesized that:

a)students' levels of conceptions (or misconceptions) in mathematics would be associated with the extent of their accuracy in interpreting geography content

b)particular forms of mathematical competence might be more strongly associated with knowledge in geography than others

Methods

Subjects

The subjects were 64 students in grades 3 - 6 from two schools of a middle class suburban public school district in northern New Jersey. Sixteen students, 8 boys and 8 girls, were randomly selected from each grade. The children were about evenly distributed in terms of high, middle, and low group placements for mathematics. Each subject was seen individually for about one hour and given a two part interview consisting of geography and mathematics sections. All interviews were videotaped.

Materials and Procedures

The study began with a search through the school district's social studies textbooks (Lofti & Ainsley, 1988) for units, chapters, and passages in which knowledge of mathematical concepts and procedures seemed to be a critical variable in developing an appreciation of geographical ideas. Following this survey, the district's mathematics textbooks (Eicholz, O'Daffer & Fleenor, 1989) were evaluated to find comparable examples of the same mathematics concepts and procedures that were embedded in the geography texts. Usually the mathematics required could be found in the grade comparable texts, but sometimes the concepts included material from more advanced grades. For example, line graphs of the type found in third grade geography text did not appear in mathematics textbooks until fifth grade. After collecting representative text material for grades 3 - 6, interview protocols consisting of "matching" mathematics and geography tasks were prepared.

While differing in specific content by grade, each protocol had the same basic components. At all grades the geography text contents were related to map skills and to demographic information presented both in narrative and pictorial formats. Students were asked to read aloud a short excerpt for each geography segment after which they were asked several questions. All the questions referred to some mathematical concepts or procedures, but tapped into three different aspects of knowledge.

The first type of geography question, stating factual information, required the student to report some mathematical factual information that had been explicitly stated in the geography text material or in the accompanying graph that students were given to read. For example, after reading some text material about immigrants who came to the United States for work opportunities between 1865 and 1930, fifth graders were shown similar information in graph forms as shown in Figure 1. The students were asked to tell how many immigrants came from Europe during certrain periods based on the information in the bar graph and were then directed to focus on the circle graphs. The latter graphs indicated the fraction of immigrants coming from different parts of Europe during particular decades and represented some of the same decades that appeared in the bar graph. In this case the factual questions asked required only that the children read off the fraction numbers in answer to the questions, "What fraction of the people came from Nortern and Western Europe between 1860-1869 (or between 1900 and 1909)?" and to tell how many millions of people came in particular decades.

The second type of geography question called for some interpretation of the given facts. It involved going beyond the explicit information provided in the text and required an application of the mathematical facts supplied or an extension of the mathematical concept described in the text to a new or expanded context. For example, for the same text selection an interpretive question required the children to apply a fraction value to a specific numerical value. In this case the children were asked to connect the knowledge presented in the two types of graphs in order to answer the question: "Were there more people coming from Northern and Western Europe between 1860 and 1869 or between 1900 and 1909?" Here as in all questions students were asked to explain their reasoning and given some prompts if they did not seem to be heading in the correct direction. In this case or example, many children immediately answered the question by citing the larger fraction section (3/5) without thinking about what the 3/5 represented in that particular context. If that was the response, the children were asked to find out: "Exactly how many people came from Northern and Western Europe between 1860 ad 1869?" and reminded to use the information in both graphs. Clearly most of the students did not know any formal procedure for computing an exact number, but some of them had some very nice informal, sensible approaches such as saying that, "3/5 was a little more than half and so the number had to be about half of the 2 million in the bar graph, or about a little more than 1 million." Then they would reason that 1/5 was something like 1/4 and 1/4 of 8 million would be about 2 million." And so, much to their suprise, the 1/5 represented a larger number of people than did the 3/5.

A third type of question, defining vocabulary used in the text, required students to provide definitions of mathematically related vocabulary encountered in the reading passages or graphs. In this fifth grade selection, one of the terms the students were asked to define was three-fifths, i.e., "What does three fifths mean?" In other contexts students were asked to define such terms as "scale" or "square mile."

In the second part of the procedure, students were asked mathematics questions that were related to the mathematical concepts and procedures that were embedded in the geography text material. Across the grades a multidude of topics were touched upon including items on:

ratio and proportion

arithmetic operations with whole

arithmetic operations with fractions

arithmetic operations with decimal numbers

line graphs

bar graphs

circle graphs

grid reading

area measurement

numeration concepts with small positive and negative integers

numeration and place value concepts for numbers of relatively large magnitude

percent.

Within reason, the numbers utilized in the mathematics sections consistently paralled the magnitude of the numbers found in the geography text. For example, when figures in the millions were presented in the geography material, students were asked to make estimates or do computations using the same or similar quantities in the mathematics section of the protocol.

The mathematics questions, like the geography questions, were also presented in three forms. In the first, the execution of computational routines, students were asked to carry out a calculational procedure that was implied or required by the geography passage. For example, in the mathematics related to the fifth grade immigration content, simple multiplication with fractions and whole number seemed necessary in order to be able to deal with the meaning of the geography information. As shown in Figure 2, for example, 2/5 x 20 was an item in this category. Some of the students knew how to carry out this computation using a school-taught procedure, while others did not. The fact that they could execute the procedure accurately, however, did not neccesarily mean that they also had a conceptual knowledge of the relationship between the numbers. Some students, on the other hand, were able to come up with informal methods for figuring out an answer without using a standard procedure. For example a student might say that he knew that "if you divide 20 by 5, that would be one fifth and 20 divided by 5 is 4. Then to get 2 fifths you would multiply 4 x 2 and that is 8." This of course was correct use a modified computational procedure that seemed to include conceptual understanding as well. Other children, of course, did not have-a clue about how to do this computation and came up wth a wide variety of interesting computational misconceptions. The details of these misconceptions are still undergoing analysis and will appear in a later paper.

In the second type of question, involving some evidence of conceptual knowledge, students were asked questions that would tap into their understanding of the mathematical content embedded in the geography text material. For example, related to the immigration selection, refer again to Figure 2, fifth grade students were asked "how many fifth were in a whole" and to compare two fraction values. The fifths in a whole question was very basic to an understanding of fractional concepts, and without this basic understanding, no real sense could be made of a geographical context utilizing fractions. The comparison of fraction values again yielded a mix of responses. Some children seemed to be wedded to utilzing essentially rote computational procedures here, sometimes accurately and sometimes not. Others seemed to have an intuitive sense of relative values and indicated this understanding with such explanations as, "If you divided something into five parts and something into eight parts, the one with the five will have larger pieces. So if you have three of both of them, the one with the fifths will have more, i.e., 3/5 > 3/8." Other students again had all kinds of misconceptions about what the numerals in each number stood for, but essentially all of these students were trying to apply the rules for whole numbers to fraction numbers and, of course, that just does not work.

The third type of mathematical task including applications of mathematical knowledge to general word problem contexts and to reading and interpreting graphs. These tasks reflected the kinds of applications that would be expected if students were to accurately understand and make sense of the mathematics found in the geography texts. Figure 2 also presents a typical word problem context used for the fraction-immigration material in which the child was asked to figure out "How many crayons would be in 3/5 of a box of crayons that holds 15 crayons when it is full?" Children were also asked to do related problems as shown in Figures 3 and 4. Both of these examples tapped children's conceptual and procedural knowledge of fractions in a graphic context.

In all types of the mathematics questions, individual children's answers varied, yet as a group they tended fall into answering patterns. In general, children's answers tended to fit categories very much related to their ability grouping placement in the school. That is, high group students were accurate and showed some flexible understanding of standard procedures. If a procedure was not known, these children usually found a way around it. The middle group students tended to be accurate and generally mechanical in their execution of learned procedures. They were likely to accept blatently ridiculous answers as correct because they believed in the reliabilty of the computational procedures they used. Finally the low group children tended to apply wild procedures, sort of distorted versions of some kind of strategy they had been taught but seemed hard pressed to recall or they used procedues that just did not fit in the current context.

Formal Scoring Procedures

I am intending to analyze some of the data obtained in great detail for patterns of conceptions and misconceptions, but began my analysis by looking for grosser group trends. All protocols, therefore, were scored quanititatively.

Within both the geography and mathematics tasks, subjects were evaluated on accuracy of answers and/or procedures used. An accuracy score of 0, 1, or 2 was obtained for each item in both domains. In general, the criteria for accuracy scores were that (0) indicated a completely wrong response or the expression of a blatant misconception, (1) indicated a partially correct response or a completely correct response obtained after some prompting, and (2) indicated a fully accurate response offered spontaneously. Based on these scores, overall mathematics and geography scores were calculated for each subject. In addition, the mathematics tasks were divided into three sections depending upon the form of mathematical competence required. These produced scores in:

a)execution of computations and routines

b)conceptual knowledge

c)applications to problems solving and graph interpretation

Results

Data were analyzed within each grade. The mean number of correct responses, expressed as percent correct, for both mathematics and geography tasks were obtained for students within each grade. Sign tests were performed at each grade to determine whether individual student's scores were systematically higher or lower on either the geography or mathematics tasks.

Further analyses of the data focused on the correlational relationship between accuracy in the knowledge and use of mathematical contents and accuracy in the attainment and application of geographical concepts within each grade level. Correlations, utilizing the Pearson product moment correlation procedure were obtained between overall geography accuracy scores and overall mathematics scores and between overall geography scores and subsections of mathematics scores.

Relative Accuracy of Overall Mathematics and Overall Geography Scores

The mean percentage of correct responses for both mathematics and geography tasks were obtained for students within each grade. As indicated in Table 1, the scores were consistently higher for geography compared to mathematics across all grades. For all groups combined, the percentage correct ranged from 12 to 97 for mathematics and 33 to 93 for geography. These results suggest that mastery of the material for the groups as was generally greater for geography than for mathematics items, but that individual differences were greater in the mathematics than the geography area.

Further analyses using sign tests were performed at each grade to determine whether within groups, students scored systematically higher on the geography or mathematics tasks. As indicated in Table 2, there was a consistent directional trend with more students having higher geography than mathematics accuracy scores at all grades. This relationship was statistically signifcant, however, only at grades 4 and 5 (z third grade = .25; z ˙ ırth grade = 2.25, $p < .05$; z fifth grade = 2.25, $p < .05$; z sixth grade = .80).

Correlations Between Mathematics and Overall Geography Scores

As indicated in Table 3, there was a statistically significant positive relationship between performance on overall mathematics and overall geography tasks at all grades (r grade 3 = .77, $p < .01$; r grade 4 = .78, $p < .01$; r grade 5 = .79, $p < .01$; r grade 6 = .87, $p < .01$). As shown in Figure 5, this correlation increased somewhat with grade.

Correlations were also obtained between overall geography scores and scores on subsections of mathematical competence. These results, also reported in Table 3 and represented in Figure 6, indicate that while the execution of computational routines and the understanding of concepts both contributed significantly to the relationship between mathematics and geography performance, there was a trend for the relationship between computation and geography performance to decrease in the higher grades while the relatonship between conceptual understanding in mathematics and geography performance tended to increase with grade level (r computation grades 3, 4, 5, 6 = .78, .78, .73, .67, $p < .01$; r concepts grades 3, 4, 5, 6 = .64, .78, .68, .90, $p < .01$)

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Discussion

The data analysed and reported on here were consistent with expectations. First, it was hypothesized that children's levels of conceptions of mathematical content areas would be associated with the extent of the accuracy of their interpretations of geography content. This hypothesis was confirmed. As reported, the data analysis indicated that there was a significant positive correlation between overall performance on the mathematics and geography items at all grades and that this relationship tended to increase from third to sixth grade. The finding suggests that as children go up in the elementary grades and increasingly abstract concepts become involved in mathematics, an appreciation of these concepts may facilitate their understanding of mathematically related geographical material.

It was also hypothesized that some types of mathematical competence would be more strongly associated with knowledge in geography than other forms of mathematical competence. The data supported this hypothesis as well. Within the mathematics domain, it was observed that as grade level went up there was a decrease in the extent of the positive relationship between the execution of computational routines and an increase in the extent of the positive relationship between conceptual understanding and overall geography performance. This suggests that some forms of mathematical knowledge are in fact more closely related to mastery of geographical concepts, but that the particular form may vary over time and development.

The findings of this study, however, do not necessarily imply that mathematically related geographical content is acquired solely as a function of applying mathematical knowledge to geographical contexts or, in fact, that mathematical knowledge is always applied to geographical contexts. The fact that most students across all grades tended to do better on geography as compared to mathematics tasks suggests strongly that there is a lot more to learning about geography than simply applying mathematical knowledge.

For example, students who are facile at tuning into relevant information and selecting important facts from incidental ones, may be at an advantage for learning both mathematical and geographical content. Moreover, having a reliable memory would be an asset for acquiring both computational procedural techniques and number facts in mathematics as well as for retaining the verbal content of geography text material even if its meaning is not clear to students. Similarly, students who approach geography text as a reading comprehension task, may be able to accurately repeat mathematically connected geography information as long as it does not require any actual mathematical activity. Graph reading, for example, may not have been used by some successful students for understanding the geography content. They may have relied more on reading the text than on interpreting the graph to get information about the geographical concepts in question. Moreover, the straight-forward factual geography questions did not require long-term retention of knowledge and so a surface rather than conceptual approach to the material could have led to success in responding to those questions.

Summary and Conclusions

Whether the knowledge of mathematics concepts and procedures is necessary for learning some kinds of geographical contents or whether some common thinking or study skills are needed for learning in both areas was not clear from this study. Certainly these findings do not suggest that mathematically related geographical content is acquired solely as a function of applying mathematical knowledge to geographical contexts. Rather, there is probably some input from common non-mathematical components related to performance in both areas. For example, factors such as selective attention, reliable memory, and motivation to achieve may be assests for learning in both disciplies. In addition, many aspects of the geography task could be managed as a reading comprehension skill that circumvent reliance on mathematical reasoning.

In general, howeve~, the fact that students who were more successful in mathematics were also more successful in geography suggests that students who are not competent in grade level mathematics may be at a disadvantage for learning geographical content. Given this possibility, it would seem that the context of geography would be an ideal place to begin to implement the intention of the NCTM standard regarding the teaching of mathematics through the content of other curriculum areas. Focusing explicitly on the meaning of the mathematics embedded in geography text, rather than treating it as incidental to the learning of geography content, would serve to provide a natural setting for discovering that mathematics has applications beyond the isolated context of "mathematics instruction." This kind of instruction should also enrich the study of geography by providing students with a conceptual context upon which they could build and retain geographical knowledge. Further research assessing the effect of this kind of instruction on both domains is needed.

Personally my intention is to delve more deeply into the individual thought processes expressed by the children in this study to find out in more detail just what misconceptions run parallel in both areas and which positive mathematical conceptions are acutually applied to the context of geography.

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Looking at the bar graph, answer the following questions.

1. In what decade did the fewest people come from Europe to the United States?

How many people came in those years?

2. In what decade did the most people come?

How many people came in those years?

3. How many people settled in the United States between 1860 and 1909?

For the next questions use the information in the circle graphs. Use the "key" beneath the circle graphs to help you.

1. What fraction of the people who came from Europe between 1860 and 1869 were from Northern and Western Europe?

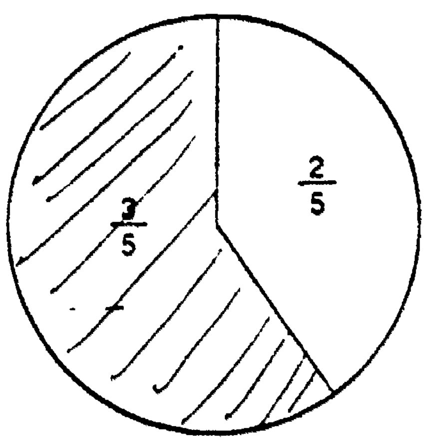
2. What fraction of people came from Northern and Western Europe between 1900 and 1909?

For the next question use the information in both the bar graph and the circle graphs.

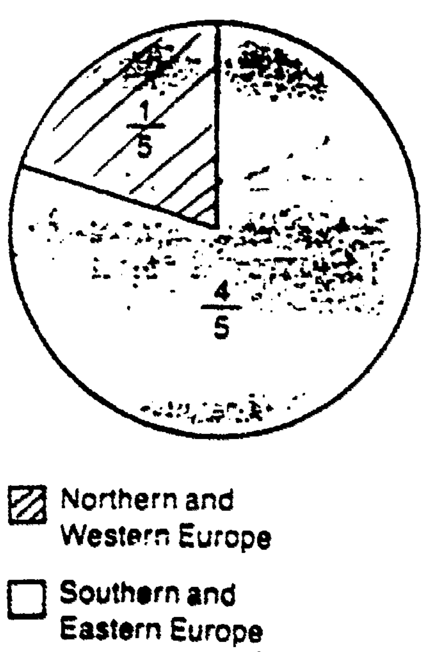
1. Were there more people coming from Northern and Western Europe between 1860 and 1869 or between 1900 and 1909?

Hint: Consider exactly how many people came from Northern and Western Europe between 1860 and 1869 and between 1900 and 1909.

European Immigration 1860–1869



European Immigration 1900–1909



Immigrants Arriving in the United States, 1860–1909

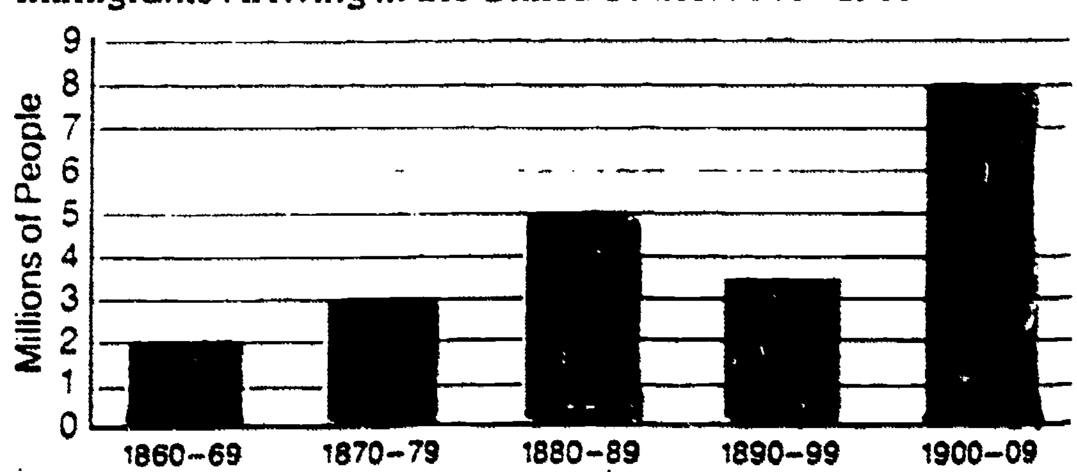


Figure 1. Geography text about immigration for fifth graders.

SAMPLE MATH CONTENT QUESTIONS RELATED TO FRACTIONS

Concepts

1. How many fifths are there in one whole?

2. Put >, <, or = between each pair of fractions

a) 3/5 1/5

b) 3/5 6/10

c) 3/5 3/8

Computation

3. 2/5 x 20 =

Application

4. How many crayons are in 3/5 of a box of crayons that holds 15 crayons when it is full?

Figure 2. Sample mathematics questions about fractions related to geography text for fifth graders.

Circle Graphs

Tanya works in a bookstore. She used circle graphs to show some data she collected.

1. Which activity takes up the greatest fraction of Tanya's time?

2. Which activity takes up the smallest fraction of her time?

3. What do you think the sum (the total) of the fractions in the graph should be?

4. Suppose Tanya works for 8 hours today.

   How many hours did she spend stocking shelves?

   How many hours did she spend ordering books?

5. If she works four days that week, for 8 hours each day, how much time will she spend making sales?

How My Working Day Is Spent

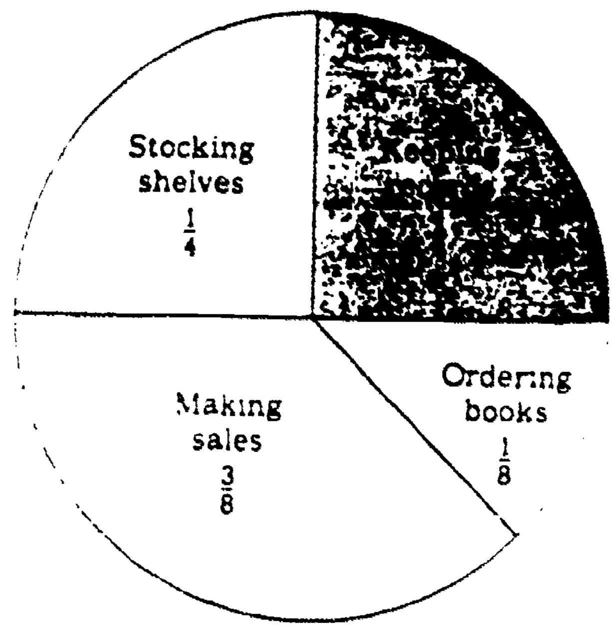
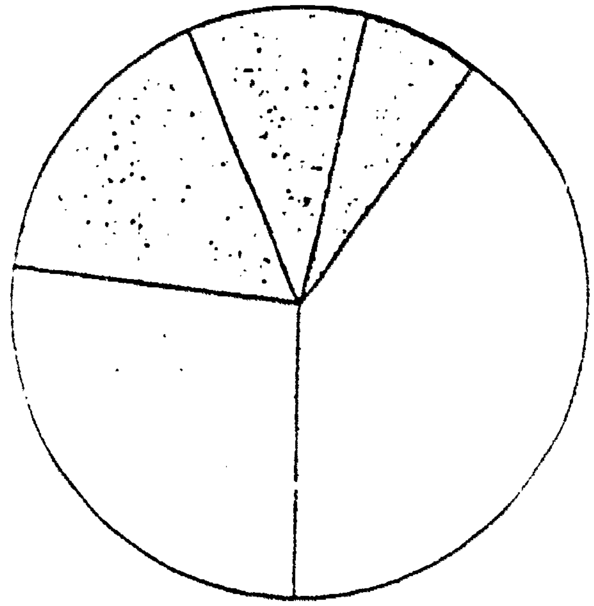


Figure 3. Applications of fractions in mathematics word problems and graphs related to fifth grade geography text material: Part 1.

Use the data in the table below to solve the problems about the incomplete circle graph

30 Animal Books Sold Last Week				
Dogs	Fish	Cats	Horses	Others
卌 卌 ||	卌	卌 |||	|||	||
12	5	8	3	2



1. Which section of the circle graph shows the sales of books for each of the animals? Label each section with the correct animal name.

2. Now put a fraction in the circle graph to show the book sales for each of the animals named.

a)dogs

b)cats

c)fish

d)horses

e)other

Figure 4. Applications of fractions in mathematics word problems and graphs related to fifth grade geography text material: Part 2.

Table 1

Mean Percentage of Accuracy Scores Attained on Mathematics and Geography Tasks

	Grade			
Task	Third	Fourth	Fifth	Sixth
Overall math	56	59	53	55
Range	12 - 87	22 - 88	18 - 97	27 - 87
Overall geography	58	65	64	59
Range	33 86	45 - 90	42 - 93	27 - 90

Table 2

Sign Tests for Determining Whether Students Performed Consistently Higher on Either Mathematics or Geography Tasks

Grade	Number of Scores Geography > Math	Number of Scores Math > Geography	Z Score for Sign Test
Third	9	7	.25
Fourth	13	3	2.25*
Fifth	13	3	2.25*
Sixth	9	5	.80

* $p < .05$

Table 3

Correlations Between Overall Geography Accuracy and Mathematics Task Accuracy

	Grade			
Task	Third	Fourth	Fifth	Sixth
Overall mathematics	.77**	.78**	.79**	.87**
Computation	.78**	.78**	.73**	.67**
Concepts	.64**	.78**	.68**	.90**
Applications (problems, graphs)	.72**	.28	.54*	.50*

* $p < .05$. ** $p < .01$.

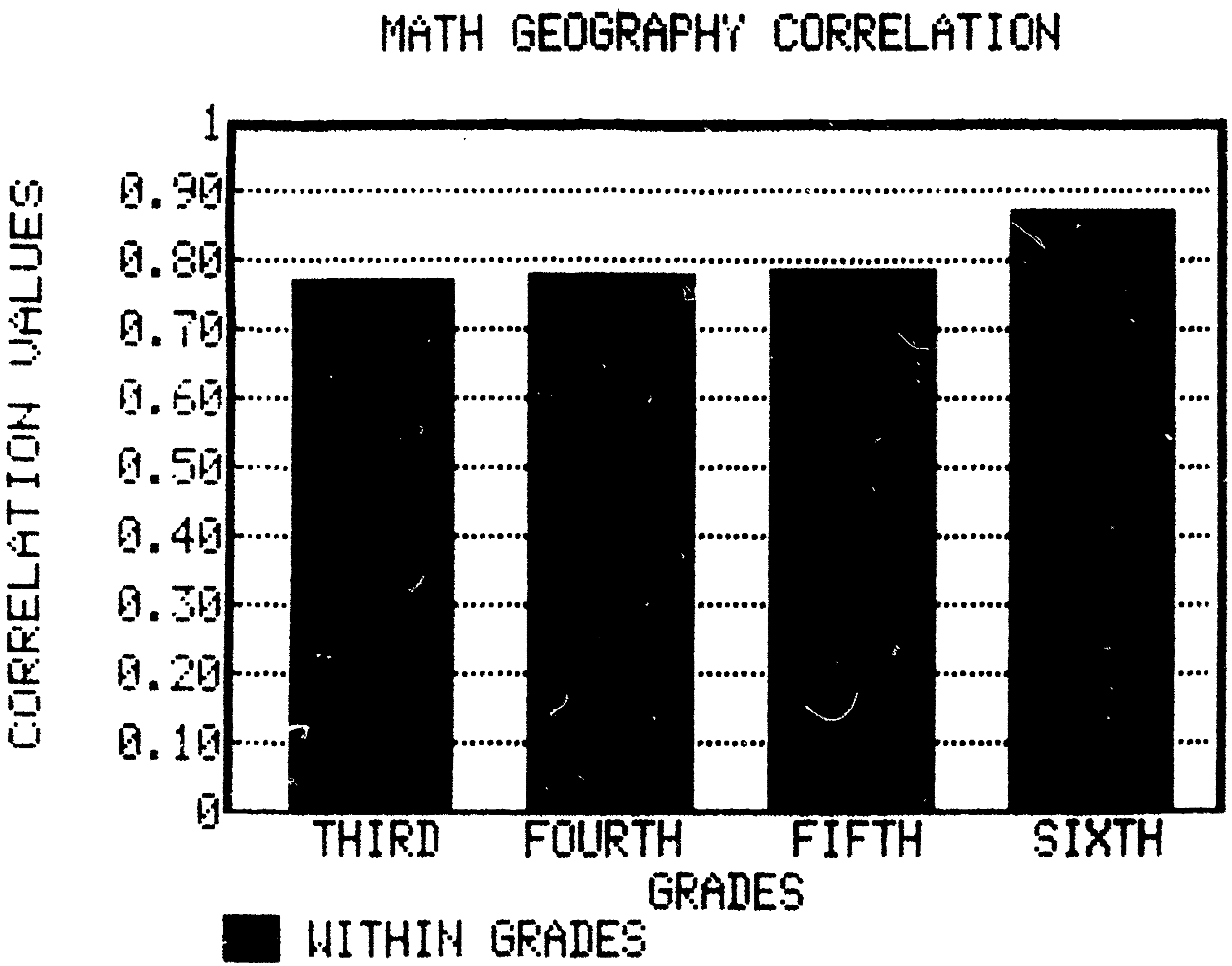


Figure 5. Correlations between mathematics and geography performance within grades.

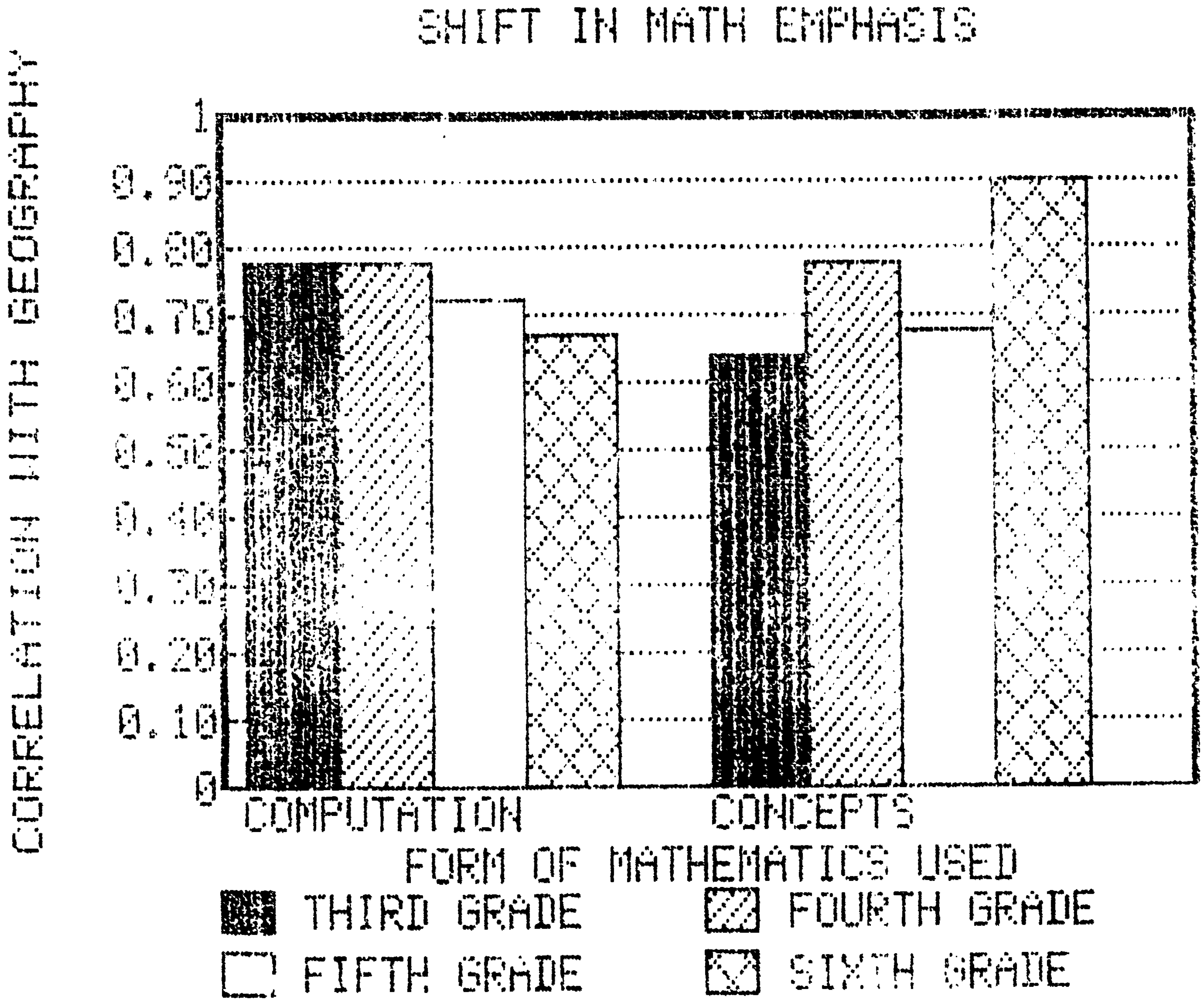


Figure 6. Correlations between mathematics concepts and geography performance compared to correlations between mathematics computation and geography performance by grade.

-25-