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Maps, charts, and graphs study of elements of difficulty and their effect on programming for instruction

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THESIS

MAPS, CHARTS, AND GRAPHS STUDY OF ELEMENTS OF DIFFICULTY AND THEIR EFFECT ON PROGRAMMING FOR INSTRUCTION

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CHAPTER I

THE PROBLEM

Statement of the problem. The purpose of this thesis is to conduct a study of the elements which cause difficulty in the reading of maps, charts, and graphs and the effect which the elements have on programming the reading of maps, charts, and graphs for instruction. The experiment was made to determine (1) if work of this kind is profitable for students and (2) which elements cause the greatest difficulty for students: (a) types of graphic aids used; (b) the numbers of aids used: (c) the depth of thought required to answer the questions.

Justification of the problem. Arkin and Colton[1] write:

> The graph is now an essential tool for the student, the business executive, the educator, the banker, the biologist, the engineer, the sociologist as well as for people in all other fields of endeavor.

Recent textbooks contain ever increasing amounts of graphic material. The student will frequently encounter graphic aids in his secondary school reading and in later adult reading. As our culture becomes more and more

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[1]Herbert Arkin and Raymond R. Colton, Graphs, How to Make and Use Them. Harper and Brothers, New York, 1936, p. 224.

statistically minded, magazines, periodicals, and books use graphic aids to present statistics. Wrightstone[2] writes:

> The use of graphs as a teaching tool seems also about to be forced upon us from without. Newspapers, magazines, and books are using graphs in increasing numbers to clarify the text or to carry data not included in the printed text. All readers of current fiction have frequent contact with graphs. This throws upon the school the responsibility for teaching pupils how to read graphs.

Students need to be taught how to read and interpret graphic materials. Systematic programming of map and chart reading is needed if students are to meet successfully the challenge of contemporary reading.

Need. There are few materials or tests on the market which attempt to answer the questions asked by this study. In most instances teaching of the reading of

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[2]J. Wayne Wrightstone, "Growth in Reading Maps and Graphs and Locating Items in Reference Books," School Review, Volume 47: p. 763, December, 1939.

graphic materials is entirely incidental. Spitzer[3] says:

> Since instruction in reading maps, charts, and graphs occurs more or less incidentally as a part of the instruction in several subject areas, the amount and quality of such teaching vary widely. . . . The level of achievement in the country as a whole, therefore, is probably lower than desirable.

It is felt that definite skills are necessary for success in the reading of graphic materials and that these skills can be programmed for teaching once a sequence of difficulty is known.

In 1960, an experiment[4] in the mass teaching of differentiated reading skills was conducted at Lynnfield, Massachusetts. One of the skills developed was that of map and chart reading. The study reports that a larger number of the 114 students in the experiment chose to work with maps, charts, and graphs than with any other materials. These materials proved to be most attractive to the students, and greater gains were reported to have been made on the Spitzer Study Skills map reading

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[3]Herbert F. Spitzer, Spitzer Study Skills Tests Manual of Directions (Yonkers-on-Hudson, New York: World Book Company, 1954) p. 5.

[4]Eleanor Fallon, et al, "Mass Differentiated Reading Skills Instruction in High School," Masters Thesis, Boston University, 1960.

than on any other skills measured.

> In spite of the fact that at the beginning of the study no student listed the reading of maps, charts, and graphs as a needed skill, more students used the maps, charts, and graph materials than any other materials that were provided. Out of 114 students, 105 students, or 92 per cent, used exercises on maps, charts, and graphs. Since these materials were varied, colorful and timely, these factors may have attracted the students rather than a genuine need. The fact remains, however, that the students did use the materials very extensively.[5]

The materials used were built, however, on a hit or miss basis without any established basis of difficulty. Only an assumed sequence was used.

> The experience working in this area indicated a cogent need for sequentially developed and extensive teaching and testing materials in reading of graphic materials.[6]

This present study is an outgrowth of the experiment in Lynnfield with the purpose of (1) rechecking the findings of the Lynnfield study and (2) determining, by structuring the materials, what elements cause the greatest difficulty for students. It is felt that

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[5]Eleanor Fallon, et al, "Mass Differentiated Reading Skills Instruction in High School," Masters Thesis, Boston University, 1960, p. 89.

[6]Ibid. p. 90.

knowledge of this kind will considerably strengthen the learning potential of materials programmed from the results of this study.

CHAPTER II

LITERATURE ON THE READING OF MAPS, CHARTS, AND GRAPHS

There is a dearth of research on the reading of maps, charts, and graphs, and especially have the contributions been few during the last twenty years. In the studies that have been reported, very little consideration has been given to the relative difficulty of the number of elements on the material read and the type of questions asked. However, these studies do give information on the relative difficulty of various types of graphs and on the ability and growth of students in reading graphs and maps. There is little to compare with the present study, but some factors relating to the reading of graphic materials can be considered.

Several studies have been carried out on the comparative difficulty in reading various types of graphic materials. In one study of this type involving students in grades four to seven, Thomas found picture graphs to be the easiest type to read. The order of difficulty for the other types included in the study was circle graphs, two dimensional diagrams, horizontal bar graphs,

and line graphs.[1]

In a similar study with junior and senior high school students, Wrightstone found picture graphs to be slightly more effective than bar graphs, circle graphs, and line graphs for the location of facts and the delayed recall of facts. For interpretation of facts and immediate recall of facts, there was no statistical difference between the two groups.[2]

Washburne's comparison of picture graphs with line and bar graphs suggested that picture graphs may be better for showing simple static comparisons. The bar graph was the most favorable for recalling relative amounts when the comparisons involved a fair degree of difficulty.[3]

The readability of circle and bar graphs by

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[1]Katheryne C. Thomas, "The Ability of Children to Interpret Graphs," The Teaching of Geography, Thirty-second Yearbook of the National Society for the Study of Education (Bloomington, Illinois: Public School Publishing Company, 1933), 492-494.

[2]J.W. Wrightstone, "Conventional Versus Pictorial Graphs," Progressive Education, XIII (1936), 460-462.

[3]J.N. Washburne, "An Experimental Study of Various Graphic, Tabular, and Textual Methods of Presenting Quantitative Material," Journal of Educational Psychology, XVIII (1927), 361-376.

college students was investigated by Eells. The circle portions were read just as rapidly as and more accurately than the bar segments.[4] In a similar study Croxton and Stryker found that the circle graph was read more accurately when the proportions were 50-50 or 25-75, but for other proportions there was little difference between the circle graph and the bar graph.[5]

Culbertson and Powers tested the effects of certain factors of graph design on the ease of graph comprehension. The results showed that bar graphs were better than line graphs for evaluating and comparing specific quantities. Circle graphs and segmented bar graphs showed data equally well. Vertical bars appeared to be slightly easier to read than horizontal bars. Quantities written on the graphs and labels or symbols

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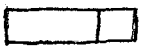
[4]W.C. Eells, "The Relative Merits of Circles and Bars for Representing Component Parts," The American Statistical Association Journal, XXI (1926), 119-132.

[5]Frederick E. Croxton and Roy E. Stryker, "Bar Charts Versus Circle Diagrams, "The American Statistical Association Journal, XXII (1927), 473-482.

rather than cross-hatched keys increased the ease of reading.6

Bar graphs were estimated more accurately than graphs of squares, circles, and cubes in a study by Croxton and Stein. There was no difference between squares and circles, and cubes were read with the least accuracy.7

Peterson compared other types of graphs by depicting five parts of a whole in eight different ways. The circle graph was read most accurately, and the multiple area column graph  was read the least accurately. In the middle group were the single bar  , multiple square column  , multiple bar  , partial cosmograph  , disc  , and multiple cylinder  graphs.8

All of these studies indicate that the picture

6Hugh M. Culbertson and Richard D. Powers, "A Study of Graph Comprehension Difficulties, "Audio-Visual Communication Review, VII (Spring 1959), 97-100.

7Frederick E. Croxton and Harold Stein, "Graphic Comparisons by Bars, Squares, Circles, and Cubes," The American Statistical Association Journal, XXII (1932).

8Lewis W. Peterson and Wilbur Schramm, "How Accurately Are Diffreent Kinds of Graphs Read?" Audio-Visual Communication Review, II (Summer 1954), 178-189.

graph is the type of graph easiest to read and that the line graph is usually difficult to read. The comparative difficulty of circle graphs and bar graphs varied among the studies.

In addition to research on the comparative difficulty of graphs, some studies have been carried out to show the ability of students to read graphs and maps and to what extent this skill is developed. In the study by Thomas, the use of graphs of varying types showed that fourth graders get little meaning from graphs, but superior fourth graders can understand simple graphs.[9]

After carrying out four studies to measure the ability of children to read diagrams, Morton Malter concluded that children have difficulty reading diagrams. For the most part he rejected his hypothesis that the ability to read diagrammatic material increases in grades four to eight. The interpretation of diagrams is an acquired skill and needs more emphasis in school. Reading of the diagrams was better when the material was familiar and when it was accompanied by orientation

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[9]Thomas, loc. cit.

or explaining lines and marks.[10]

While these studies indicate the difficulty of students in reading graphic materials, other studies show that the skill is developed. From one such study Wrightstone concluded that there is a gradual growth in the ability to read graphs and maps in grades seven to twelve.[11]

Whittemore found that map reading ability is developed by students. However, because of a lack of readiness training, only the exceptional child can interpret maps. It was concluded that step-by-step training in map reading should be provided.[12]

Other conclusions involving the understanding of diagrams were made from a study by M.D. Vernon. Information on a diagram is not necessarily understood better

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[10]Morton S. Malter, "Children's Ability to Read Diagrammatic Materials," Elementary School Journal, XXXIX (October 1948), 98-102.

[11]J.W. Wrightstone, "Growth in Reading Maps and Graphs and Locating Items in Reference Books," School Review, XLVII (December 1939), 759-766.

[12]K.T. Whittemore and M. Melvina Svec, Graduation of Map Skills (tentative edition; Buffalo, New York: College Co-op Bookstore, New York State College of Teachers, 1947).

than when it is in table form. Certain types of data are shown best on certain types of diagrams, but material that is complex and unfamiliar is read with difficulty irrespective of the type of diagram used. Understanding is improved when the diagram is accompanied by a verbal explanation. Training is necessary to enable people to read diagrams effectively.[13]

The elements in graphs were considered for their relative difficulty in a study of Agricultural Communication. Circle graphs appeared to be the best way to illustrate parts of the whole. Specific recall was greater when simple visual patterns with scant data were used. The accuracy of estimates dropped when the number of dimensions on the graph increased or when the number of elements included in a single presentation increased.[14] Croxton and Stein also found the reading accuracy to be less when the number of dimensions increased.[15]

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[13]M.D. Vernon, "Presenting Information in Diagrams," Audio-Visual Communication Review, I (Summer 1953), 147-158.

[14]National Project in Agricultural Communication, Say It With Pictures (Agrisearch, Vol. I, No. 6. East Lansing: Michigan State University, 1955).

[15]Croxton and Stein, loc. cit.

The correlation of education and intelligence with skill in reading graphic materials was measured in two studies. The National Project in Agricultural Communication found accuracy in graph reading to be related to age, education, and training or experience in using them.[16] A moderate correlation between numerical, verbal, and abstract reasoning scores and graph reading was found in the other study by Culbertson and Powers. There was a moderate but lower correlation between intelligence test scores and graph reading ability.[17]

These studies show that training in the reading of maps and graphic materials is needed. The research on the comparative difficulty of varying types of graphs gives some results which can be beneficial in planning the needed training. However, the lack of research in this field makes apparent the need for further investigation such as that undertaken by the present study.

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[16]National Project in Agricultural Communication, loc. cit.

[17]Culbertson and Powers, loc. cit.

CHAPTER III

THE DEWEY EXPERIMENT

PROCEDURE

To determine the influence of certain factors upon the difficulty of reading maps, charts, and graphs, special materials were constructed to allow consideration of these factors. The materials used in the study consisted of ninety units divided into six categories of fifteen units each. The six categories were as follows: (1) factual questions using one graphic aid; (2) inferential questions using one graphic aid; (3) factual questions using more than one graphic aid; (4) inferential questions using more than one graphic aid; (5) factual questions using a single book or pamphlet; and (6) a problem to solve with intent to involve inferential thinking and using two books or pamphlets.

Each category was divided into three groups of five units each according to the type of maps, charts, or graphs used. The three groups were (1) charts and graphs of two elements; (2) charts and graphs of more than two elements; and (3) maps.

The materials used in constructing the units were obtained from magazines, newspapers, financial reports, transportation schedules, tourist brochures, and road

maps. Hammond's American History Atlas, the Matthews-Northrup New World Atlas, and the Rand McNally World Atlas were also used.

In preparing the units for use, the materials in categories one to four were mounted on oaktag, and the brochures and pamphlets in categories five and six were placed in envelopes. Five questions were prepared for each unit. For categories one to four,these were printed on the oaktag below the map, chart, or graph. In categories five and six, the questions were typed on cards which were enclosed in the envelopes. In all cases the units were self-correcting with the answers printed on the back of the oaktag or card.

The thirty members of the experimental group were students enrolled in high school remedial reading classes, with a grade range of nine to twelve. Nearly all of the students in the reading classes received a score on the California Reading Test which was at least one grade level below their grade in school.

Except for a brief introduction, the experimental group received no instruction on how to read maps, charts, and graphs. The students worked on the prepared units about fifteen minutes two times a week for eleven weeks. Each student completed in random order thirty-six units,

or two units from each group of five.

The control group consisted of twenty-six other high school students who were selected to match the experimental group. They received no instruction or practice in reading skills in general or in reading maps, charts, and graphs.

At the beginning of the study, the experimental and control groups were equated on the following variables: (1) sex; (2) age; (3) I.Q. score on the Otis Mental Ability Test, Gamma Test; (4) score on the California Reading Test; and (5) score on Form Bm of the Spitzer Study Skills Test 3, which deals with reading maps, charts, and graphs. At the end of the study, both groups were given alternate Form Am of the Spitzer Study Skills Test 3 to measure the improvement made during the study in the students' ability to read maps, charts and graphs.

PRESENTATION AND ANALYSIS OF DATA

Equating the Groups. The equating of the groups at the beginning of the study yielded a Chi Square of .461 for sex ratio. As shown on Table I, the critical ratios received were 1.229 for age; .276 for I.Q. on the Otis Mental Ability Test, Gamma Test; 1.928 on the California

TABLE I

COMPARISONS OF VARIABLES ON THE EXPERIMENTAL AND CONTROL GROUPS AT THE BEGINNING OF THE STUDY

Variable	Group	No.	Mean	Standard Deviation	σ_m	Critical Ratio	Significance
Age	Experimental	30	191.667	14.256	2.645	1.229	Not Significant
	Control	26	186.269	17.540	3.508		
Otis Mental Ability Test	Experimental	30	34.800	10.533	1.956	.276	
	Control	26	35.577	10.140	2.028		Not Significant
California Reading Test	Experimental	30	61.000	13.640	2.533		
	Control	26	68.500	14.760	2.952	1.928	Not Significant
Spitzer Study Skills Test 3	Experimental	30	21.433	5.208	.967		
	Control	26	23.115	6.000	1.200	1.151	Not Significant

Reading Test; and 1.151 on the Spitzer Study Skills Test 3, Form Bm. Since none of these results shows a significant difference, the groups may be considered comparable at the beginning of the study.

Gains Made. The Spitzer Study Skills Test, Form Am, was given at the end of the study to determine the improvement in the students' ability to read maps, charts, and graphs. Table II reports the scores made on the pretest and the posttest, and the comparisons between the scores.

As is indicated by the critical ratios in Table II, the difference in pretest and posttest scores is statistically significant at the five percent level. The change made by the experimental group shows a strong trend of significant improvement. At the same time the control group made almost no improvement.

Again referring to Table II, the two-year gain made by the experimental group as compared with the two-month gain of the control group further shows the improvement made by the experimental group. The gain made by those who had practice in reading maps, charts, and graphs was definitely greater than the gain made by those who had no practice.

Order of Difficulty. The results did not support the hypothesized order of difficulty. The type of aid used

TABLE II

COMPARISON OF SCORES ON THE SPITZER STUDY SKILLS TEST 3

Test	Group	No.	Mean	Equivalent	Standard Deviation	σ_m	Critical Ratio	Significance
Pretest	Experimental	30	21.433	8.6	5.208	.967	2.039	Significant at the 5% level
Posttest	Experimental	30	24.300	10.6	5.498	1.021		
Pretest	Control	26	23.115	10.0	6.000	1.200		
Posttest	Control	26	23.423	10.2	4.682	.936	.202	Not Significant
Pretest	Experimental	30	21.433	8.6	5.208	.967		Not
Pretest	Control	26	23.115	10.0	6.000	1.200	1.151	Significant
Posttest	Experimental	30	24.300	10.6	5.498	1.021		Not
Posttest	Control	26	23.423	10.2	4.682	.936	.633	Significant

did not have as great effect as anticipated.

Type of Aid: The type of aid used had a limited influence upon the order of difficulty, although there was a small increase in difficulty with an increase in the number of elements on the graph or chart. Table III shows that graphs and charts of two elements were easiest to read with maps being only slightly more difficult. Graphs and charts of more than two elements were read with least ease.

According to Table V, the time required to complete the units was least for charts and graphs of two elements, somewhat more for charts and graphs of more than two elements, and greatest for maps.

Number of Aids: Difficulty in reading was affected only slightly by the number of aids used as is shown in Table IV. Units involving only one graphic aid were read with very little more accuracy than units of three graphic aids or whole books. There was no real difference between the results for whole books and units where three graphic aids were mounted together.

However, Table V shows that the time required to complete a unit was affected by the number of aids involved with units of one graphic aid using the least time, units of three graphic aids next, and whole books

TABLE III

THE TYPES OF MATERIALS IN THE EXPERIMENT

WITH THE PERCENTAGE RESULTS

Group	5 questions right	4 questions right	3 questions right	Less than 3 questions right
1. Graphs and charts of two elements	40.8%	31.7%	12.2%	15.3%
2. Graphs and charts of more than two elements	25.8%	32.8%	20.0%	21.4%
3. Maps	33.6%	33.3%	17.5%	15.6%

requiring the most time.

Type of Question: The type of question asked had the greatest influence upon the accuracy in reading the materials. According to the results shown in Table IV, factual questions were definitely the easiest to answer. There was little difference between working out a problem and answering inferential questions, but the problems were slightly more difficult.

The same order of difficulty was indicated by the time required to complete each unit. Table V shows that factual questions were answered a little more quickly than inferential questions, but the problems required more time. The greater difference between the time required for problems and inferential questions is probably affected by the fact that the problems involved the use of whole books, while the inferential questions did not.

It can be seen, therefore, that difficulty in reading maps, charts, and graphs increases somewhat when the number of elements on the graphic material increases and when the number of graphic aids increases. However, the greatest increase in difficulty occurs when questions of an inferential or problematic type are to be answered. The time required to read the graphic material is similarly affected by the factors in the material and questions.

TABLE IV

THE DESIGN OF MATERIALS IN THE EXPERIMENT FROM EASIEST TO HARDEST WITH THE PERCENTAGE RESULTS

Category	5 questions right	4 questions right	3 questions right	Less than 3 questions right
1. Factual questions one graphic aid	46.1%	31.1%	10.6%	12.2%
2. Inferential questions one graphic aid	26.7%	34.4%	18.9%	20.0%
3. Factual questions three graphic aids	38.3%	33.3%	14.5%	13.9%
4. Inferential questions three graphic aids	21.1%	33.9%	21.7%	23.3%
5. Factual questions whole book	39.4%	35.0%	13.9%	11.7%
6. Problems two books	28.9%	27.8%	20.0%	23.3%

TABLE V

AVERAGE NUMBER OF MINUTES REQUIRED

TO COMPLETE EACH UNIT

Category Group	Graphs and charts of two elements	Graphs and charts of more than two elements	maps	Average for the category
1. Factual questions one graphic aid	2.5	3.4	3.6	3.2
2. Inferential questions one graphic aid	3.8	4.2	4.4	4.1
3. Factual questions three graphic aids	3.6	4.0	4.2	3.9
4. Inferential questions three graphic aids	4.2	5.2	5.5	5.0
5. Factual questions whole book	4.4	6.3	6.7	5.8
6. Problems two books	5.4	6.8	7.9	6.7
Average for the group	4.0	5.0	5.3	

CHAPTER IV

THE LEACH EXPERIMENT

PROCEDURE

Groups. The experiment was conducted at the Masconomet Regional High School, Boxford, Massachusetts. Out of the possible eight homogeneously grouped seventh grade sections, the three top ones were chosen for this experiment. From these three sections an experimental group of fifty-four students and a control group of thirty students were formed.

Table I shows the complete statistical data for the experimental and control groups. The two groups were equated on the following variables: (1) a group I.Q. score, (2) a study skills score, (3) a reading score and sex ratio in the group. All of the students had taken the California Test of Mental Maturity at the end of Grade 6, and the I.Q. scores were taken from that source. The average I.Q. for the experimental group was 128.4. The average I.Q. for the control group was 131.1. Form A of the Spitzer Study Skills Test 3, Understanding Graphs, Tables, and Charts, was given to determine study skills proficiency. Seventh grade percentiles on this test showed the average of the experimental group to be 64, and the control group average to be 63.2.

TABLE I

CHARACTERISTICS OF EXPERIMENTAL AND CONTROL GROUPS

Characteristic Group	Number	Mean	S.D.	σm.	C.R.	Level of Significance
I.Q. California Test of Mental Maturity						
Experimental	54	128.34	14.585	2.001	1.001	Not significant
Control	30	130.83	7.720	1.426		
Spitzer Study Skills Test 3, Understanding Graphs, Tables & Charts						
Experimental	54	24.852	7.508	1.031	.235	Not significant
Control	30	24.534	4.70	.873		
Diagnostic Reading Survey Test						
Experimental	54	59.11	13.91	1.911	1.275	Not significant
Control	30	55.5	11.25	2.089		

Sex	Men		Women		Chi-square	Level of Significance
Experimental	30	29.6	24	24.4	.032	Not significant
Control	16	16.4	14	13.6		

Form A of the Diagnostic Reading Survey Test was administered to obtain a reading score. The percentile norms of Grade 7 on this test showed the average of the experimental group to be 85.4, and the control group average to be 86.2.

Design of the Materials. The design of the materials included ninety exercises. These were divided into six categories of fifteen exercises each comprising: (1) factual questions using one graphic aid; (2) inferential questions using one graphic aid; (3) factual questions using more than one graphic aid; (4) inferential questions using more than one graphic aid; (5) factual questions using a single book or pamphlet; and (6) a problem to solve with intent to involve inferential thinking and using two books or pamphlets. Each of the six categories was divided into three equal parts; (a) charts or graphs of two elements; (b) charts or graphs of more than two elements; and (c) maps.

Construction of the Materials. The maps, charts and graphs were obtained from a wide variety of current publications. Road maps were obtained from various service stations. Travel folders, transportation schedules, and street guides were secured from a travel agency. Books used were the 1960 World Almanac,

Hammond's World Atlas, and Goode's World Atlas.

All of the graphic aids that were of suitable size were mounted on pieces of oaktag with each category or group of materials in a different color. In Groups 1-5, the five questions which were asked in each exercise were printed under the graphic aids, and the problem in the sixth group was printed on the envelope containing the materials. Each of the ninety exercises was designed to be self-correcting. The answers to the questions were printed on the reverse side of the oaktag or envelope. The exercises were all numbered on index tabs attached to them. Table II shows the plan of the materials.

Use of the Materials. The experiment was conducted in conjunction with the regular geography classes of these sections. Those in the experimental group began to work on the materials on Monday, November 26, 1960. It was arranged for them to work on the exercises for periods of fifteen minutes three times a week until Wednesday, February 15, 1961, a period of approximately eleven school weeks. When it became apparent about half way through the experiment that the time allotment was not sufficient for completion of the experiment, the students were encouraged to use additional free time.

TABLE II

PLAN OF THE MATERIALS

Group	Color	Numbers	Kind of Questions	No. of Aids	No. of Elements
1	Manila	1-15	Factual	1	1-5 - Graphs of 2 6-10 - Graphs of more than 2 11-15 - Maps
2	Yellow	16-30	Inferential	1	16-20 - Graphs of 2 21-25 - Graphs of more than 2 26-30 - Maps
3	Orange	31-45	Factual	2-3	31-35 - Graphs of 2 36-40 - Graphs of more than 2 41-45 - Maps
4	Blue	46-60	Inferential	2-3	46-50 - Graphs of 2 51-55 - Graphs of more than 2 56-60 - Maps
5	Red	61-75	Factual	Book	61-65 - One page 66-70 - More than 1 page 71-75 - Atlas or road map
6	Envelopes	76-90	Problem	2 Books	76-80 - One page 81-85 - More than 1 page 86-90 - Atlas or road map

Supervised study periods were utilized.

There was no planned sequence for the use of the materials. Students were instructed to use a card of a different color each time. Doing the exercises in a random order was most important in this experiment. If the exercises were done on the assumed pattern of difficulty, the knowledge and skill gained from one level would transfer to the next level making it less difficult. Therefore, selecting the exercises on a random basis was the only way the effect of learning could be controlled and be a true measure of the difficulty measured. To maintain a check on the random order in which the exercises were done, answer sheets were prepared on sheets of five different colors, white, green, pink, blue, and yellow, with room for doing six exercises on each sheet. At the end of the experiment, these sheets were arranged by order number, and by flicking through the pile, the flash of colors proved that the exercises were done on a random basis. For each exercise, in addition to the answers, the following information was recorded on the answer sheet:

1. Name of student
2. Exercise Number
3. Order Number
4. Time taken to do the exercise
5. Score (percentage correct)

The role of the teacher in the experiment was very slight. The students were permitted to ask questions on interpreting a graphic aid or to clarify their reading of an aid; however, such questions were infrequent.

As was reported in the Lynnfield study, the materials in their experiment were of considerable interest to the students. The same was true of this experiment. On the average a high degree of interest in the work was maintained, and frequently the students asked to be allowed to work on the exercises for more than the forty-five minutes allowed each week in the geography classes.

On February 16 and 17, 1961, post tests were given to both the experimental and control groups. These included Form B of the Diagnostic Reading Survey Test and Form B of the Spitzer Study Skills Test 3, Understanding Graphs, Tables, and Charts. The results of these are discussed under the findings.

FINDINGS

Gains Made. Tables III and IV present all of the data of the post tests with critical ratios run between the two groups and between the pre and post tests. There were no statistical differences between the experimental

TABLE III

COMPARISON OF GROUPS ON PRE AND POST TESTS ON SPITZER STUDY SKILLS TEST 3 AND DIAGNOSTIC READING SURVEY

Characteristic Group	Number	Mean	S.D.	σ_m.	C.R.	Level of Significance
Spitzer Study Skills						
Test 3 Post-Test						
Given Feb.16,1961						
Experimental	53	26.698	5.432	.753	.687	Not significant
Control	30	25.934	4.434	.823		
Diagnostic Reading						
Survey Test Post-						
Test given Feb.17,1961						
Experimental	53	59.035	10.85	1.504	1.184	Not Significant
Control	30	56.335	9.245	1.716		
Spitzer						
Experimental						
Pre-Test	54	24.852	7.508	1.031	1.446	Not significant
Post-Test	53	26.698	5.432	.753		
Control						
Pre-Test	30	24.534	4.70	.873	1.162	Not significant
Post-Test	30	25.934	4.434	.832		
Diagnostic Reading						
Experimental						
Pre-Test	54	59.11	13.91	1.911	.030	Not significant
Post-Test	53	59.035	10.85	1.504		
Control						
Pre-Test	30	55.5	11.25	2.089	1.275	Not significant
Post-Test	30	56.335	9.245	1.716		

TABLE IV

COMPARISON OF EXPERIMENTAL GROUP'S PRE AND POST TEST VOCABULARY SCORES ON THE DIAGNOSTIC READING SURVEY TEST

Experimental Group	Number	Mean	S.D.	m.	C.R.	Level of Significance
Diagnostic Reading Survey Test Vocabulary Section						
PRE-	53	35.17	41.816	5.798	.317	Not significant
POST-	53	33.302	6.778	.939		

and control groups on the Spitzer post test, nor was there any statistically significant improvement between the pre and post Spitzer tests of both groups. Although not statistically significant, the gains of the experimental group do show a strong trend toward improvement, but not large enough to rule out chance factors above the five per cent level.

There was no significant improvement made on the Diagnostic Reading Survey Test. Improvement in general reading skills or vocabulary was not expected as it was not a purpose of the study; however, the reading was measured before and after to determine if there were any unanticipated transfer of maps and charts reading skills to general reading skills. Apparently there was none.

Grade scores based upon the norms given for the Spitzer Study Skills Test and the Diagnostic Reading Survey Test were next determined. Again there was no significant improvement in reading. But as reported in Table V, in the Spitzer Map Reading Test the experimental group advanced from grade level 10.9 to 12.7, an eighteen month gain. The control group advanced from 10.8 to 11.9, an eleven month gain. This represents a substantial gain for the experimental group over the control group. Considering the length of the experiment, an advance of three months would be normally

TABLE V

COMPARISON OF AVERAGE GRADE ACHIEVEMENT OF GROUPS ON THE PRE AND POST TESTS ON THE SPITZER STUDY SKILLS TEST 3, AND THE DIAGNOSTIC READING TEST

	Pre-Test	Post-Test
Spitzer Study Skills Test 3		
Experimental	10.9	12.7
Control	10.8	11.9
Diagnostic Reading Survey Test		
Experimental	10	10
Control	9.4	9.6

expected. Thus the experimental group's gain was six times greater, and the control group's gain was not quite four times greater than expected.

Order of Difficulty. The empirical findings of the experiment did not support the order of difficulty in the hypothesized arrangement in the original design. Table VI shows the hypothesized arrangement, the percentage of questions answered in each of the six categories, and the percentages of accuracy in each. From the table the following information becomes apparent.

(a) Type of aid used. The type of aid used, whether a chart or graph of only two elements, a chart or graph of more than two elements, a map, a whole book or pamphlet, or two books or pamphlets, caused the least difficulty. But as the number of elements within an aid increased, the difficulty increased also. Table VII shows the statistical comparisons of the differences among the types of aids used. In this table the lower mean reflects the difficulty and represents the more difficult type of aid used. Three of these comparisons show significant differences. In each of these three by examining the means, maps are found to be the easiest. The remaining three critical rations show trends toward significance. The table as a whole shows that maps were the easiest type of aid used, charts and graphs of two

TABLE VI

THE DESIGN OF MATERIALS IN THE EXPERIMENT FROM EASIEST TO HARDEST WITH THE PERCENTAGE RESULTS

	Categories	Total Answered	5 Questions Right	4 Questions Right	3 Questions Right	Less than 3 Questions Right
1.	Factual Questions One graphic aid	99.3%	59%	29.8%	8.8%	2.4%
2.	Inferential Questions One graphic aid	98.7%	32.2%	33.8%	19%	15%
3.	Factual Questions 2-3 Graphic Aids	87.5%	43.8%	34.2%	14.3%	7.6%
4.	Inferential Questions 2-3 Graphic Aids	66.7%	29.6%	24.2%	18.7%	27.5%
5.	Factual Questions Whole Book	54.3%	46.9%	27.7%	14.8%	10.6%
6.	Problems Involving 2 books	48.6%	63.3%	4.4%	10.1%	21.2%

TABLE VII

COMPARISON OF RELATIVE DIFFICULTY OF TYPES OF AIDS USED AND NUMBER OF STRUCTURAL ELEMENTS

	Number	Mean	S.D.	σ_m.	C.R.	Level of Significance
CHARTS & GRAPHS						
2 Elements	982	82.03	21.38	.682	1.214	Not Significant
More than 2 Elem.	920	80.978	26.740	.886		
2 Elements	982	82.03	21.38	.682	5.882	Highly significant
Maps	1021	87.242	18.40	.567		
2 Elements	982	82.03	21.38	.682	1.795	Not significant
Books	816	79.21	40.43	1.416		
More than 2 Elem.	920	80.978	26.740	.886	5.959	Highly significant
Maps	1021	87.242	18.40	.567		
More than 2 Elem.	920	80.978	26.740	.886	1.056	Not significant
Books	816	79.21	40.43	1.416		
Maps	1021	87.242	18.40	.567	5.266	Highly significant
Books	816	79.21	40.43	1.416		

elements came next, then charts and graphs of more than two elements, and finally whole books were the most difficult.

(b) The Number of Aids Used. This factor did not have the importance anticipated. The original design expected the difficulty to increase when the questions involved an increasing number of graphic aids: difficulty to grow from one graphic aid to more than one graphic aid to a whole book to more than one book. However, as Table VIII shows, the empirical findings did not support this. The use of whole books and pamphlets caused only slightly more difficulty than the 1-3 graphic aids already mounted together, and the difference was not statistically significant.

Table IX shows the statistical comparisons of the differences among the number of aids used. These critical ratios show highly significant differences between the number of aids used in all but two instances. Here, as in Table VII, the lower mean represents the more difficult of the combination of aids compared. The findings show that the use of two books and of one graphic aid were of approximately equal difficulty. When compared with the other numbers of aids used, they both show significant differences, but when compared

TABLE VIII

THE EMPIRICAL FINDINGS SHOW THE ORDER OF DIFFICULTY TO BE FROM EASIEST TO HARDEST

1. Factual Questions - one graphic aid
2. Factual Questions - 2-3 graphic aids
   Factual Questions - whole book
3. Problems - 2 books or pamphlets
4. Inferential Questions - one graphic aid
5. Inferential Questions - 2-3 graphic aids

TABLE IX

COMPARISONS OF NUMBERS OF AIDS USED

	Number	Means	S.D.	σ_m	C.R.	Level of Significance
1 Graphic Aid	1486	90.760	18.420	.478	5.211	Highly significant
2-3 Graphic Aids	1315	86.580	24.660	.652		
1 Graphic Aid	1486	90.760	18.420	.478	4.296	Highly significant
Whole Book	432	85.540	24.20	1.117		
1 Graphic Aid	1486	90.760	18.420	.478	1.104	Not significant
2 Books	386	92.740	34.260	1.748		
2-3 Graphic Aids	1315	86.580	24.660	.652	.804	Not significant
Whole Book	432	85.540	24.20	1.117		
2-3 Graphic Aids	1315	86.580	24.660	.652	3.302	Significant
2 Books	386	92.740	34.260	1.748		
Whole Book	432	85.540	24.20	1.117	3.471	Significant
2 Books	386	92.740	34.260	1.748		

with each other, the difference is not statistically significant. The category of two books, however, has the higher mean. Similarly the category of 2-3 graphic aids is shown to be about equal in difficulty to one book. Based upon these statistical comparisons of difficulty, the order from easiest to hardest is one graphic aid, two books involving one or two aids, 2-3 graphic aids, and one book involving multiple aids.

(c) Kind of Questions. Table VIII clearly shows that the kind of questions asked was the greatest single determining factor in what causes difficulty in maps, charts, and graph reading. No matter what kind of aid was used or how many aids were used, factual questions were the easiest for the students. Problems involving two books came next in order of difficulty. The inferential question in the second and fourth category caused the greatest difficulty. The depth of thought required to answer the question proved to be the element causing the most difficulty in the reading of maps, charts, and graphs. Table X presents a random sampling of questions with responses.

Table XI reports the statistical differences among the types of questions asked. All of them are highly significant. In all comparisons of the kinds of questions asked, factual questions had the higher mean and were

TABLE X

RANDOM SAMPLING OF QUESTIONS WITH RESPONSES

FACTUAL:

What two years marked the largest exports of American autos?

Right	Wrong
72.7%	27.3%

What span of years is shown on the chart indicating the percentage of homes owned or rented?

Right	Wrong
94%	6%

INFERENTIAL:

Why is the western part of Australia so sparsely settled?

Right	Wrong
86.5%	13.5%

How does the percent of personal income outstanding in installment credit in the U.S. compare with that of Britain?

Right	Wrong
70%	30%

PROBLEM:

You are a resident of Salem, Mass., and you want to go to the movies in Boston one afternoon. The train is the only available transportation to you. The movie you want to see is Ben Hur. On a Wednesday, what time will your train leave Salem to get you to Boston in time for the show, and if the movie is over at 6:30, what train can you catch back to Salem? (Allow ½ hour to get from theater to station)

Right	Wrong
71.8%	28.2%

TABLE XI

COMPARISONS OF KINDS OF QUESTIONS

	Number	Means	S.D.	σ_m	C.R	Level of Significance
Factual Questions	1918	99.580	15.780	.364	17.426	Highly significant
Inferential Questions	1315	86.580	24.660	.652		
Factual Questions	1918	99.580	15.780	.364	4.056	Significant
Problems	386	92.740	34.260	1.748		
Inferential Questions	1315	86.580	24.660	.652	3.302	Significant
Problems	386	92.740	34.260	1.748		

the easiest. Problems are shown to be next in order of difficulty, and inferential questions caused the most difficulty.

The time element recorded bears out the accuracy of these findings. As the number of elements in the graphic aid increased, as the type of aid became more complex, and when the questions asked required more depth of thought, the length of time required to do the exercise increased. The time spans recorded ranged from less than one minute to somewhat over twenty minutes. As reported in Table XII, fifteen comparisons were made to determine if the differences in the time taken to do the exercises in one level were statistically different from the time taken to do the exercises of another level. In this table,lower mean represents the shorter time taken to do an exercise. All of these comparisons,except two,show critical ratios of significant or highly significant differences. The two comparisons which show no significant differences represent transitions from one element of difficulty to another. For example, level two has inferential questions with one graphic aid, and level three has factual questions but with 2-3 graphic aids. Similarly, level four, inferential questions with 2-3 graphic aids, when com-

TABLE XII

COMPARISON OF TIME ELEMENTS BETWEEN LEVELS

		Number	Mean	S.D.	σ_m	C.R.	Level of Significance
Level	1	790	138.140	73.650	2.622	7.330	Highly significant
	2	785	211.760	331.937	11.102		
Level	1	790	138.140	73.650	2.622	14.984	Highly significant
	3	696	208.798	103.320	3.919		
Level	1	790	138.140	73.650	2.622	19.865	Highly significant
	4	528	264.147	132.60	5.777		
Level	1	790	138.140	73.650	2.622	15.274	Highly significant
	5	429	276.082	178.80	8.642		
Level	1	790	138.140	73.650	2.622	16.223	Highly significant
	6	385	321.040	214.80	10.965		
Level	2	785	211.760	331.937	11.102	.251	Not significant
	3	696	208.798	103.320	3.919		
Level	2	785	211.760	331.937	11.102	4.174	Significant
	4	528	264.147	132.60	5.777		
Level	2	785	211.760	331.937	11.102	4.571	Significant
	5	429	276.082	178.80	8.642		

(table continued on next page)

(Table XII Continued)

		Number	Mean	S.D.	σ_m	C.R.	Level of Significance
Level	2	785	211.760	331.937	11.102	7.003	Highly significant
	6	385	321.040	214.80	10.965		
Level	3	696	208.798	103.320	3.919	7.929	Highly significant
	4	528	264.147	132.60	5.777		
Level	3	696	208.798	103.320	3.919	7.090	Highly signficant
	5	429	276.082	178.80	8.642		
Level	3	696	208.798	103.320	3.919	9.639	Highly significant
	6	385	321.040	214.80	10.965		
Level	4	528	264.147	132.60	5.777	1.148	Not significant
	5	429	276.082	178.80	8.642		
Level	4	528	264.147	132.60	5.777	5.397	Highly significant
	6	385	321.040	214.80	10.965		
Level	5	429	276.082	178.80	8.642	3.220	Significant
	6	385	321.040	214.80	10.965		

pared with level five, factual questions using a whole book, shows no statistical differences in the time element. These findings on the time element strongly support the original design of the materials and show that the time order can be arranged as follows: Level 1, Level 3, Level 2, Level 4, Level 5, and Level 6.

Summary. The findings of this experiment report that significant improvement on the basis of grade scores on the Spitzer Study Skills Test 3 was made by the experimental group over the control group. The elements which cause difficulty in maps, charts, and graph reading in order of difficulty from least to most were (a) type of aid used; (b) number of elements within the aid; and (c) the depth of thought required to answer the question. Table XIII presents the found order in which these elements can be programmed for study.

TABLE XIII

OBTAINED ORDER IN WHICH MAPS, CHARTS AND GRAPHS SHOULD BE PROGRAMMED FOR INSTRUCTION FROM EASIEST TO HARDEST

Type of Aid	Number of Aids Used	Kind of Question
1. Maps	1. One graphic aid	1. Factual Questions
2. Charts and graphs of 2 elements	2. 2-3 graphic aids	2. Problems
3. More than 2 elements	3. Whole Books	3. Inferential Questions
4. Whole Books		

CHAPTER V

CONCLUSIONS

THE DEWEY EXPERIMENT

(1) Skill in reading maps, charts, and graphs needs to be taught. Even with practice the students encountered difficulty in reading and interpreting graphic materials which came from sources which are in daily use.

(2) Practice with materials such as those used in this study results in an improvement in the students' skill in reading maps, charts, and graphs. This is evidenced by the substantial improvement made by students who received the practice as compared with the very slight improvement made by those who had no practice.

(3) Difficulty in reading graphic materials is determined more by the type of question to be answered than by the type or number of materials used. Inferential questions are difficult for students to answer. There is a need for training students in how to approach this type of question and how to find the needed information from the graphic aid.

(4) Material to develop skill in reading graphic materials, and especially for the purpose of answering inferential questions, needs to be constructed. There

is very little material of any type available to teach these skills, and there is no material which is designed to follow any sequential order which has been validated by research. The order of difficulty as indicated by this study could be used in constructing these materials. There is need for only a few units involving one graphic aid and factual questions, but more practice should then be available with units involving several graphic aids and inferential questions. There is a need for special emphasis in training students to relate ideas and draw inferences from the information that is available.

(5) Further study needs to be carried out to investigate the gains made when the validated sequence is used. There might also be some research to correlate the order of difficulty indicated in this study with the order of difficulty of earlier studies which dealt with different types of graphs.

THE LEACH EXPERIMENT

(1) Work of this kind is profitable for students. The Lynnfield study reported a gain of two years and seven months. This study supports that gain by reporting a grade score advance of eighteen months over an expected gain of approximately three months.

(2) Teaching the reading of maps, charts, and graphs in a sequence makes the difference. The Lynnfield study, where an assumed sequence was used, showed greater gains over this study where the exercises were done on a random basis.

(3) Graphic aids do need to be taught. Emphasis needs to be put on how much the aid really tells and how many elements are included in it.

(4) The findings on the number of aids used calls attention to a factor which may account for the books not being as difficult as expected. The locational skills of the experimental group may have been sufficiently good to make the use of a whole book or books hardly more difficult than the aid openly presented on a card. Further study should include a measure of locational skills in testing the order of difficulty.

(5) More practice is needed in seeing interrelationships between graphic aids and of transferring

and combining information gained from more than one. The students in the experiment showed markedly less success in the categories involving 2-3 graphic aids than in those involving only one.

(6) Logical steps can be taken to program this study as a part of regular classroom work: (a) The graphic aids must be built as there is little currently on the market purporting to do this; (b) The elements which cause difficulty should be structured in the order of difficulty as shown by this experiment. To prepare ninety such exercises to be completed would be unnecessary. A few would accomplish mastery of the easier categories, and greater emphasis should be put on the kind of question asked. Factual questions would best be given first to pull out the specific information. Then materials with questions designed to make the student interpret, draw inferences, and make conclusions should be introduced.

(7) This experiment has shown that students cannot answer questions involving some depth of thought with anything like the same facility with which they can answer questions of fact. It would appear that inferential thinking is much more difficult than multiple tasks involving locational skills in securing facts.

(8) The relationship of thinking to reading needs to be further explored. Programming for instruction the reading skills for maps, charts, and graphs is a start at overcoming the pitfalls in this complex relationship. The discovery of the difficulty patterns involved in the thinking may have implications in other reading areas outside of maps, charts, and graph study.

COMPARISON OF THE CONCLUSIONS OF BOTH EXPERIMENTS

The Dewey study and the Leach study were carried on simultaneously, one in the South with high school students and the other in the North with seventh grade students. The exercises in each experiment were different in content, but the same criteria were used to build them and the same procedures were used to conduct each experiment.

Only the Dewey experiment reported a statistically significant difference above the five per cent level on the Spitzer pre and post tests; however, the Leach experiment had a trend toward improvement. This is probably attributable to one important difference between the two studies. In the Leach study both groups were in geography classes and worked with graphic materials. In the Dewey study the control group was drawn from regular high school classes, and only the experimental group worked with maps, charts, and graphs. Hence, Dewey's experimental group had statistically greater gains than the group with no direct map-reading experience.

The findings from both studies in comparison with the Lynnfield study bear out that map, charts, and graph reading skills need to be taught in a sequence. Much

less significant gains were achieved on the random order in which the exercises were done. This presents a sharp contrast to the Lynnfield experiment where greater statistically significant gains were reported when only an assumed sequence was used. For real improvement in graphic reading skills, a sequence of difficulties based upon the findings of these studies should result in significant gains. Further research is necessary to test this assumption.

The conclusions from both studies agree as to which elements cause the greatest difficulty for students in maps, charts, and graph reading. The type of graphic aid used caused the least difficulty; the numbers of aids used came next; and the depth of thought required to answer the questions was the most difficult factor.

The experiments have pointed out a need for exercises to develop reading skills for maps, charts, and graph reading programmed in a known sequence of difficulty which are not currently on the market. If the sequence found in these studies bears up under further experimentation, a substantial improvement of these reading skills may prepare many students for greater reading proficiency in a media which is more and more in daily use.

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