This is to certify that the

thesis entitled

PLACE-FINDING ON MAP PROJECTIONS:
AN EXPERIMENT WITH CHILDREN

presented by

Bonnie Kay Jones

has been accepted towards fulfillment
of the requirements for

M.A. degree in Geography

Judy M. Olson
Major professor

Date February 25, 1992

PLACE-FINDING ON MAP PROJECTIONS:

AN EXPERIMENT WITH CHILDREN

By

Bonnie Kay Jones

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

Department of Geography

1992

ABSTRACT

PLACE-FINDING ON MAP PROJECTIONS: AN EXPERIMENT WITH CHILDREN

By

Bonnie Kay Jones

Young children are adept at recognizing straightforward projections such as miniature cars and houses. They also recognize objects as seen from different viewpoints. Map projections are similar because they are two-dimensional visual representations, but not all map projections mimic the globe using linear perspective. This study examines the ability of children to recognize locations on world map projections. As an elementary skill necessary for using small scale maps, this study has implications for readiness to use maps of extensive regions of the earth.

Second, fourth, and sixth graders were tested individually. Students were given ten map projections of the world and were asked to locate 20 places on the maps that were shown to them on a globe. Significant improvement in ability occurred as grade level increased. No significant difference was found among projections or locations. Mean scores were second grade 17%, fourth grade 37%, and sixth grade 64%.

ACKNOWLEDGMENTS

I would like to thank my advisor, Dr. Judy Olson, for her guidance and assistance and Sam Paris for his patience. I extend a special thanks to Gloria Helfand who incouraged me to pursue this in the first place.

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Chapter 1

INTRODUCTION

From a very early age, children understand the idea of projection. They play with toy cars and doll houses that represent real objects. The projection of objects on the eye from different viewpoints results in ready recognition of familiar items. Map projections are two-dimensional visual representations that are similar to the reduced, simplified object and to objects seen from different angles, but they differ in that the basic shape of the original object is drastically changed and not all map projections mimic the globe using the linear perspective we experience in everyday perception of objects.

A major work in the understanding of child development in understanding space is The Child's Conception of Space (Piaget, 1956). Piaget's studies of children included those pertaining to the ability of children to utilize certain concepts including projection in the general sense. Early in life, the child must develop a sense of perceptual constancy, i.e., understanding that an object does not change even though it is viewed from different angles or sides. This development is a continuous process. Piaget concluded that a child can begin to grasp the concept of visual realism or perspective and understand a two dimensional coordinate system by the age of nine or ten.

However, as Muehrcke (1974) has put it: "Mapping is much more than a simple projection and 'miniaturization' operation. A map does not merely preserve all features of reality in scaled down form" (pp. 13-14). A map is highly selective in what it shows and the items depicted (e.g., a dot and city name) bear little if any resemblance to the original. Furthermore, a map necessarily distorts the shape of the spherical earth represented. It is usually not a straightforward perspective representation and various projections distort the earth in very different ways. "Thinking and visualizing in three-dimensional space is difficult enough, but trying to derive notions in three dimensions, when you have only seen them as they are represented in distorted two-dimensional fashion, is even more difficult" (Bartz 1970, p. 23).

One often sees the entire earth depicted on a map projection, an image that is simply impossible under the rules of perspective projection. Map projections are highly abstract in the sense that one cannot look at a spherical surface from any point and see the surface in the way that it is depicted on the projection.

Can we assume that a nine-year-old who has developed the sense of perceptual constancy and of coordinate systems can somehow use these abilities to see the correspondence of points on a globe and those on a map? As Bartz (1970) phrased it, "when you move from a grid on a flat surface to an invisible, arbitrary grid on a ball, and try to understand the ways in which this spherical grid is rearranged as it is projected onto the flat map, there are grave perceptual and conceptual problems" (p. 23). If those problems delay the development of an ability to deal with map projections, at what age does the ability develop? Do experiences in the normal course of children's lives lead to development of the ability, or is more or less direct instruction required? Do all children of normal mental ability reach the stage of being able to see the correspondence of globe locations and map locations or are there people who never acquire the ability?

This study does not address all of these questions. Rather, it is a straightforward benchmark study that examines the ability of children of different age groups (7-11) to recognize correspondence of place location between map projection and globe. Testing an elementary skill necessary for the use of small scale maps, the study has implications for readiness to use maps of extensive regions of the earth's surface. As Boehm and Petersen (1987) put it, "if students cannot find significant locations on outline maps, it is unlikely that they have the background to perform geographical abstractions of a higher order" (p. 167).

Chapter 2

LITERATURE REVIEW

The question of when children are able to locate places on various map projections does not seem to have been answered in the literature. Much literature has been written on when to introduce various map concepts and map reading in school but little pertains to map projections.

For many years, educators have discussed the value of map use and map reading in education and in what grade they should be introduced. Opinion and evidence vary widely. There is an implicit if not explicit notion that it is important to know when a child can do certain tasks before deciding when to teach certain materials in the curriculum. Knowing when children can use map projections would, according to this view, be important in planning when to employ map projections in school activities. Alternatively, the information could be useful in planning when to teach skills that would facilitate learning to use map projections.

Studies even referring specifically to projections are relatively rare. If they recommend introduction at specific grade levels, the levels vary considerably from one study to another and many are based on general experience with teaching children, not on data gathered from rigorously designed experimentation.

In my search for literature on children's understanding of map projections, I reviewed a range of materials on the teaching of map reading skills. It was important to look at the general category of literature because projections would not likely be taught as a separate module in the way they might be in a college cartography course. Rather, I expected authors to recognize the matter of projections within the context of elementary map reading skills. I also wanted to know about the ages at which general skills are taught and when map projection skills are likely to develop.

Traditionally, the teaching of map reading skills is started sometime in the middle grades, 3 through 5. Hahn (1936), Shryock (1939), Anderzhon (1954), Thralls (1958), McAulay (1964), Neperud (1977), and Boehm & Petersen (1987) all address in one way or another the matter of when to teach map skills to children in the middle grades.

Hahn (1936) discussed the failure of children to do well in the Hahn-Lackey standardized test for geographic knowledge. Part of the failure is attributed to the lack of map reading ability by the children. Hahn suggests that map reading should begin in the lower grades. "By the end of the fourth grade children would have acquired the map habit and with it considerable skill in reading different kinds of maps" (p. 230). A more extensive use of maps in all grades is stressed.

Shryock (1939) outlined levels of map learning for various grades. Shryock suggested that the use of a simple map should start in the third grade. The fourth grade should include use of the globe and additional simple maps. In the fifth grade, different types of maps with different scales could be used to compare areas. Shryock mentioned projections only when stressing that when using a base map of the world, it should not be on the Mercator projection.

Anderzhon (1954) showed "that many 6 and 7 year olds are curious about maps but it is not until about fourth grade, ages 9 to 10 years, that approximately 65 percent of the children use maps and globes ... for locating places and tracing trips" (p. 238)

In Thralls' book, The Teaching Of Geography (1958) there is a set of guidelines for when to teach certain aspects of geography. Grade three is suggested as the appropriate time to introduce maps to children. Third graders should understand that a globe is a representation of the earth and they should be able to recognize and use symbols on simple maps.

McAulay (1964) determined that fourth grade children are sufficiently mature to learn map skills and that maps do help fourth grade children understand social studies content better. He did not feel it was necessary to teach map skills as a separate entity.

Neperud (1977) did a study of spatial representation using 296 children. He found that, beginning at the fourth grade, students were drawing maps to represent the large-scale environment in an exercise on giving directions. His study suggests that the fifth grade would be the earliest in which to have the students draw small-scale environment maps.

Boehm and Petersen (1987) believe that "for young children, learning simple geographical facts can invite more advanced geographical inquiry" (p. 168).

There seems to be a more recent trend to introduce map concepts in first and second grade and, in some cases, even kindergarten and preschool (Chase, 1955; Sabaroff, 1958; Bathurst, 1961; McAulay, 1966; Atkins, 1981; Hawkins and Larkins, 1983; Blades and Spencer, 1986; Pritchard, 1989). Teaching simple map skills usually means teaching children about symbols, locations, and cardinal directions. Suggested activities often include having children make a map of their classroom or schoolyard. The abstract concepts of map projection are not a part of the understanding necessary for the activities they propose.

Chase (1955) did a study of grade school children for basic skills related to maps. The study was done in hopes of learning "more about what skills could be taught where and when and how" (p. 309). Part of the study used the results from the Iowa Every Pupil Tests of Basic Skills in Map Reading. The results showed that it was possible for first graders to learn simple map reading skills, such as recognizing symbols, and that ability in graph reading started at grade three. The ability to use polar projections was listed as part of general map skills selected for the study, but this ability was not mentioned in the results of the study.

Sabaroff (1958,1961) said that if geography is taught in elementary school at all it is usually started in the fourth grade, where students are expected to use the maps placed in front of them. However, these children will not be ready to use them without previous instruction in the earlier grades. Sabaroff suggested a program of study to observe and analyze the students' home and school in the first grade, neighborhood in the second grade, and local community in the third grade. Similar to those of other authors, her activities do not involve map projections.

Bathurst (1961) also believed that early exposure is important and that first graders can understand simple maps. He observed that map reading skills cannot be learned in one lesson and should be covered over several years.

McAulay (1966) tested a class of second graders at the beginning and end of the school year for their geographic understandings. The children were not given any special geographic instruction above the standard social studies program. McAulay discovered that there was growth in comprehension of some geographical concepts related to geographical terms as well as location, direction, and distance. By the end of second grade the students understood what a map and a globe were and how to use them for simple tasks.

Atkins (1981) tested four and five year old preschool children using experimental and control groups. The experimental group received four weeks of instruction on simple map and globe concepts. The control group continued with the regular program of activities. The experimental group showed statistically significant gains in map and globe skills; however, these children could not handle abstract locations such as 'city' and 'state'.

Hawkins and Larkins (1983) noticed a lack of practical map skills even among students who have 'well-developed school map skills.' They devised a series of 'real life mapping activities' for young students which starts out with mapping the student's desk and classroom and includes a field trip around the neighborhood and the mapping of what they saw.

Blades and Spencer (1986) summarize a series of recent studies to determine the ability of 4 to 6 year olds. They found that "children as young as 3 years old can use maps to locate places in small environments, and that after the age of 4.5 years many children can use a map to follow a route" (p. 52). Some of the studies had the children make maps of their school and routes to school.

Pritchard (1989) developed some simple games to teach primary school children beginning map skills such as cardinal directions and map symbols. She used simple maps in conjunction with stories so that the students could trace the route of the characters in the books.

Others think that map skills should not be taught until at least sixth grade or later, the strongest argument for this schedule coming from George T. Renner (1951) and relating closely to concerns about map projections. He

claimed that children are learning too much too soon of facts and figures before they understand the relationships between man and environment. Renner stated that "even the basic facts about a map projection require both plane geometry and simple analytics for their understanding. Therefore, to expect third, fourth, or fifth grade children to use the map, in any adult sense of that term is folly" (p. 69). In his outline for geographic education he has the fifth grade begin with a simple map that can be made into a globe with a few parallels on it. The sixth grade "should progress from local community to county, to state, to nation" and receive a gradual introduction into "the adult map with full coordinates" (p. 74). His outline continues through the ninth grade without mentioning instruction on projections, which I assume he leaves until the high school level.

Miller (1985) in reviewing literature, found data that showed that "concepts often are presented prematurely or in a way that is not appropriate for students" (p. 32). He used as an example a study of 498 students by Sorohan (1962), the results revealing that "mental ages typical of fifth graders were needed for understanding map legends, symbols, and abbreviations. Average sixth graders could master an understanding of different uses for maps, but it took a seventh grade mental age to comprehend and use a grid system" (p. 32).

Many stress a map program of continuous instruction at all levels from kindergarten to 12th grade (Kennamer, 1965;

Lee and Stampfer, 1966; Arnsdorf, 1985; Miller, 1985). Lee and Stampfer (1966) state that "many of the advantages of a suitable program for primary-grade children is (sic) dissipated in later years due to a lack of continuity from grade to grade" (p. 627).

The articles described above show a wide range of opinion regarding the abilities of children to use and understand maps. The information concerning projections tend to be more implicit than explicit.

The concepts of latitude and longitude are important tools in being able to understand map projections. The grid on a map is an effective way to see distortion on map projections and it provides a net that can be helpful in relating location on the globe to location on the map. Although children as young as six can use a simple grid (Blades and Spencer, 1986), latitude and longitude are much more difficult concepts.

Many studies and study guides discuss latitude and longitude, which are traditionally introduced in fourth grade (latitude) and fifth grade (longitude) according to Kennamer (1962), who observes that these basic concepts are not well understood by many students, even at the college level. One reason for this lack of understanding could be that "the concepts are verbalized and memorized but never visualized, or ... they are done so only in two dimensions" (p. 9-10). Thralls (1958) and Harris (1967) place introduction into fifth grade (latitude) and sixth grade (longitude).

Anderzhon (1954) did a study of 750 students in grades one through eight related to map use. She said that "by the end of junior high school (eighth grade, age 14), pupils can and do use latitude and longitude as a guide for discovering distortions on a map" (p. 240). The study suggests, then, that an understanding of latitude and longitude comes somewhat later than suggested by Thralls and Harris. 'Introducing' latitude and longitude, however, is not the same as 'using' them to discover distortion, which may come later than introduction.

Miller (1985) in referring to the study by Sorohan that tested 498 students, stated that "Understanding latitude and its use, longitude and its use and the concept of degrees in latitude and longitude usually were not acquired by students with less than 10th grade mental ages" (p. 32). Presumably, differences in tasks led to the higher age at which performance was satisfactory (assuming mental age matched grade levels in the Anderzhon study).

These studies suggest that fourth and fifth graders are not ready to understand latitude and longitude, concepts related to using map projections. The use of latitude and longitude is not, however, necessary to every task involved in understanding projections. The ability to see correspondence of globe locations and map locations does not depend on use of the graticule even though it may be useful to do so.

A few studies do focus on map projections and when to introduce them. Some articles mention map projections but do not offer any time scale. Fuller (1943) discussed the advantages and disadvantages of using polar projections in school but did not specify when to introduce them. He said that by the time students complete Junior High School, they should have the skills involved in map reading. Gregoria (1943) created a map reading course for high school and college students who have not had a map reading course since grade school. Her course included five map projections: Mercator, conic, polyconic, azimuthal and polar. Her course assumed that high school students could handle map projections. Belthuis (1950) had an overview of map reading skills for grade school geography teachers which included the basics of map projections but did not say in which grade map reading should be taught. Williams (1950) discussed the choice of map projections for teaching global relationships. He covered the construction and qualities of a variety of projections but never stated when these lessons of map construction should begin. Steward (1970) gave a very detailed review of projection types and how to present them, using other planets to encourage interest and comparison. He addressed his paper to the geography teacher but did not mention grade level.

Kennamer (1965) outlined six basic skills which included the "ability to compare maps and to make inferences ... concerning the distribution of things shown on maps ... which serves as a capstone to all other skills developed" (p. 457). He emphasized that work on this skill should take place at all grade levels. Speaking about projections "one would hope that every geography classroom would include ... an equal-area physical-political world map" (p. 457).

A few studies do mention the grade in which map projections should be introduced. Thralls (1958) and Harris (1967) think that map projection should be taught in senior high school. Shryock wants projections taught in junior high school and Forsyth (1944) suggests fifth grade as a good time to start.

Shryock(1939) suggested that, in Junior High School, isotherms and isobars can be shown on maps and contour maps can be introduced. She encouraged the use of maps on different projections but warned that "the Mercator and Gall projections may be employed, but the children should be reminded of their inaccuracies, or distorted areas" (p. 186).

Forsyth (1944) had a well-written course in map reading for the upper elementary and junior high school students that included the idea of projections and compared two equal area maps and a polar projection. The course was to be taught to students as early as fifth grade.

Thralls (1958) stated that polar projections should be introduced in senior high school (grades 10,11,12) along with contour maps. A high school student should be able to understand the concept of projection enough to see advantages and disadvantages in various map projections.

In a review of pre-1967 literature pertaining to children's abilities to read maps, Rushdoony (1968) concluded that there tends to be a grade-to-grade progression in children's ability to read maps. In his list of map reading skills, he said that sixth graders could make inferences from different types of maps "regarding regions, weather, agriculture, transportation, relief, and ... map projections"(p. 218).

The literature pertaining to maps and children, then, speaks broadly to the questions of when certain types of maps and skills should be introduced. The suggestions and sequences tend to skirt the fundamental issue of children's understanding of the relationship between flat maps and the spherical globe.

Chapter 3

METHODOLOGY

THE PROBLEM

We do not know very clearly what the relationship is between grade level and map reading skills. The literature is especially weak in revealing the relationship between grade level and the ability to use map projections. Surely the simple task of being able to see that points (places) on the globe have a corresponding location on the flat map is a key to a child's ability to deal with map projections in any meaningful way.

I chose to examine the specific question of when children become able to find globe locations on map projections. Indirect as the reviewed literature might be, I think a reasonable approach to examining that question is to look at second through sixth grade. Children ranging in age from 7 to 11 should show a significant increase in the ability to deal with projection in general. It seems reasonable to think that they could also progress to an operational understanding of the more complex form of projection involved in representing the spherical earth on a flat surface.

A study of individual children over time was beyond the scope of the study, but some evidence can also be gathered about whether the ability develops gradually or suddenly for the groups of children as a whole. If it develops gradually, there will be an even change from second to fourth to sixth graders. If it develops suddenly, either second and fourth or fourth and sixth grades will show a sharp difference but the other pair will not.

HYPOTHESES

The primary hypothesis is that the performance of the students using map projections does not improve as the grade level increases. The alternate hypothesis is that the performance of the students using map projections does improve as the grade level increases. A secondary null hypothesis is that there is no change in rate of performance improvement. The alternative hypothesis is that there is a significant increase between a pair of grades (second and fourth or fourth and sixth) but not between the other pair.

Map projection is a complex phenomenon and a test that utilizes one projection could show different results than would a test with another. Different locations might be more or less difficult to locate, as well. These inherently complicating factors lead to additional secondary hypotheses. One null hypothesis is that all the projections are of the same difficulty. The corresponding hypothesis is that some projections are significantly more difficult than others. Another null hypothesis is that all places are of the same difficulty. The corresponding hypothesis is that some places are significantly more difficult than others.

More specifically, in this case I am hypothesizing that coastal locations are easier than interior ones because the coastline gives a reference line for placing locations that is lacking for interior locations.

TEST DESIGN

To test children's ability to see locational correspondence between globe and map projection, I designed a test that involved showing children a place on the globe and asking them to mark it on a map.

The test included ten map projections and twenty locations. Each student attempted to locate two places on each projection; the two places varied from one child to another so that, in aggregate, every place was located on every projection.

The test was intended to collect benchmark information about how well children perform this fundamental map projection task. The results of the test can provide a background for further research which should provide guidelines for educators teaching and utilizing projections in educational activities.

PILOT STUDY AND DESIGN CHANGES

To test my hypotheses, I initially produced a booklet of twelve map projections covering all or most of the world. The exercise consisted of having students locate two places, one interior and one coastal, on each map, as I pointed to the places on the globe. With each place, I gave some bit of information relating to each place to hold the students' interest. For example, when I pointed to Moscow on the globe I would say "On this map see if you can locate Moscow. Moscow is a large city you often hear about in the news. Put a dot on the map where you think Moscow should be and an M next to it".

For my pilot study, I tested 7 students: two seventh graders, three sixth graders, and two third graders. They were not all within the grades I wanted to test, but they gave me a chance to test the design and make minor corrections. I tested all the students separately, except for two who were tested together to see if testing more than one student at a time was feasible.

The two third graders had a harder time locating places than the sixth graders. They took more time and had more wrong answers. One of the third graders recognized the shape of the area in which the place was to be located but could not find the shape on the projection and did not use surrounding shapes for locational purposes.

In the case of the two students tested together, I had them sitting across from each other with a barrier between them so they could not see the maps being marked by the other student. It was more time consuming (for each student) to test two at a time because I had to keep turning the globe back and forth to show the point to each student. Testing two students together did not take as much of my time as testing two students individually and it was more fun for the students, but it did not allow me as much opportunity to observe. Observing was important to the study because I could see where the students were having problems and sometimes what methods they were using for solving these problems.

After the first four students were tested, the test design was re-evaluated and some changes were made. I had twelve projections at the pilot stage; two were dropped because the test was too long and the students were getting bored after about ten minutes of the repetitive task. The dropped projections were the Albers and the gnomonic oblique; neither (as I had rendered them) covered the full globe (all the others did). Two maps had some figure ground ambiguity corrected, and one location was changed. At the beginning of the pilot study, each map had two specific places to be located by the student, and the two places for a specific projection were the same for all the students. The pilot study demonstrated that difficulty of location and difficulty of projection would not be separable with that design. I decided to rotate the pairs of locations among the maps to eliminate the problem. However, this introduced a new problem. The locations that were easy to locate on the projection they were chosen for were not always easy to locate on the other projections. If I were doing the test over, I would change some of the locations, trying to eliminate the ones that 'fell off the edge' of the orthographic projections, or I would re-center these projections to eliminate the problem.

I also changed from using a 12 inch globe to an 16 inch one (Rand McNally Mark IV) so that locations were easier for the children to see. Most of the places were large cities, and on the larger globe they were highlighted in red with various geometric shapes depending on population size, making them more visible. Also, on the larger globe, the graticule was less visible so the students had to rely primarily on shape recognition for locating the places, and they were less likely to be confused if latitude and longitude increments on the projections differed from those on the globe.

As a result of the pilot test experience, several questions were added to be asked after the test was over. I asked the students what types of maps they used in school and at home, and I also asked which points were hard for them to locate on the maps. I chose one or two places that they answered correctly and asked them how they knew they should put the point where they did. I also asked if they thought maps were fun, and how often they looked at maps on their own. I decided to ask the teachers what map skills their students had learned in class. With the changes made in the design of the study, I was ready to start testing.

SUBJECTS

I chose to test second, fourth, and sixth graders (ages approximately 7, 9, and 11) because the educational literature on map reading suggested that general age range as a likely one in which the skill might develop. It was also a logical range given the general Piagetian finding

that nine-year-olds have developed a sense of perspective. The skill of matching globe and projection locations is related but more complex. I omitted third and fifth grades from my project to keep it manageable.

The tests were conducted in the Lansing and East Lansing, Michigan, school districts. I contacted both school boards and sent them a copy of my proposal. I sent the school principals a letter outlining my research, and then called to answer any questions the principals might have. The principals talked to the teachers of the specific grades involved, then contacted me to indicate which teachers would be able to accommodate my needs. I made an appointment to meet with the teachers to set up testing schedules and provide consent forms to be signed by parents. Most of the teachers were very helpful and were pleased to cooperate. I left it up to the teachers to say when I could schedule individual children to leave their classes for the test.

The students tested were a representative sample from the two districts because they were taken from several classes of students at various schools. The students were from a wide range of socio-economic backgrounds inferred from their respective neighborhoods. Several students had been born in other countries. In Lansing, I tested two sixth grades, two fourth grades, and one second grade. In East Lansing, I tested one sixth grade, one fourth grade, and two second grades. I wanted to test at least 36 students from each grade, so I tried to test 12-15 students from each of three classes at different schools in each grade. The total number of students tested were 34 second graders, 36 fourth graders, and 39 sixth graders. It took seven months to complete the testing of the students, from late September to March, 1987.

Table 1: AGES OF STUDENTS

	6yr	7yr	8yr	9yr	10yr	11yr	12yr	13yr
2nd gr	1	23	8	2				
4th gr			3	22	11			
6th gr					2	31	5	1

THE MAPS

Ten varied projections were used in the testing. They appear in Appendix C with error locations marked (to be discussed later). They range from fairly globelike (orthographic) to highly abstract (interrupted with interior split). The maps were small scale, with continent outlines covering all or almost all of the earth. The graticule was removed from the continents to give better figure ground. All of the maps were on 8 1/2 X 11 paper and were stapled together to form a booklet for easy handling. The maps were oriented with "north at the top" to the degree possible, although some were in portrait orientation (long direction of the sheet oriented vertically) and others were in landscape orientation (long dimension oriented horizontally), requiring rotating the booklet 90 degrees clockwise.

Students were allowed to rotate the maps as they chose, but having north as consistent as possible largely eliminated the problem of orientation affecting the results. "The psychological work suggests that map readers will have problems when confronted with a map that is not in the usual north-at-the-top orientation" (Cerny and Wilson, 1976).

The maps were arranged as follows:

ORTHOGRAPHIC CONVENTIONAL

ORTHOGRAPHIC OBLIQUE

GNOMONIC PIECEWISE

LAMBERT POLAR

GOODE'S INTERRUPTED HOMOLOSINE

MERCATOR CONVENTIONAL

CONFORMAL IN A SQUARE

TRANSVERSE MERCATOR

OBLIQUE OVAL (BARTHOLOMEW)

INTERRUPTED WITH CONTINENTAL SPLIT (SINUSOIDAL)

The maps were taken from various sources. The orthographic, gnomonic, and Mercator were created on a computer using a mainframe computer and the Cartographic Automatic Mapping (CAM) Program Version 5. The rest were redrawn from examples in various books and atlases including Deetz and Adams (1945), Lee (1976), and Roblin (1969).

The particular version of the gnomonic projection I used (showing the whole world in sections) I designed myself. The gnomonic is an azimuthal on which any straight line represents a great circle. It is impossible to show uninterrupted an entire hemisphere, much less the entire earth, on the gnomonic. I used the polar version from the poles to 30 degrees n and s respectively, and then plotted the equatorial sections as a conventional gnomonic with points on the equator (90 degree increments) at the centers of the sections. Because the scale changes drastically over the map, I designed it so that the scales are the same at 30 degrees, where the polar and regular projections meet (see map in Appendix C).

PROCEDURES

Each student was tested individually, out of the classroom and away from distractions. The student sat on one side of the table and I sat at the adjacent left side so the student could see the globe and I could see what the student was doing. The student was given a booklet and a pencil. Each student was instructed to put his or her age and grade on the cover page while the test procedure was explained. The instructions were as follows: "This is a globe. In front of you is a book of maps. I am going to show you a place on the globe, and you have to locate that same place on the map. I will show you two places for each map. There are ten maps." Testing began after they acknowledged the instructions. Resting the globe on the table and using a pencil, I pointed to the first location, said the name of the location, and an item of interest about the location. The item of interest did not give any hints for placing the location (see Appendix A). I made sure that the location was centered on the globe facing them, and that north was up. After they penciled in a dot and looked up, they were given the next location. After placing the second location, they were asked to turn the page, and we repeated the procedure while I observed their behavior.

After going through all the maps, we went back through them to identify which maps or which locations they thought were difficult. Then we turned to the last page where there were some questions. I asked these questions and the students wrote down their responses:

(1) What kinds of maps have you seen in school: globe, world, U.S., Michigan, city, road?

(2) At home, do you have: a globe, an atlas or book of maps, road maps?

(3) Do you think maps are fun?

(4) Do you read maps, not for school, not because you have to, but just for fun? If yes, do you do it once in a while or often. (It was left up to them to define once in a while and often.)

Last, I went back through the maps to find a location that was answered correctly. I pointed it out to them and asked them if they could explain how they knew where to put the dot for that location. What did they look for? If they had no right answers, I did not ask that question. When we were through, I thanked them for taking my test and told them I hoped they had fun doing it.

Notes were not taken during the test, but notes were made afterwards on the answer booklet after the child had left (if there was something unusual or interesting about their behavior during the test).

With ten maps, the test took 15-20 minutes per student. Most of the students seemed to enjoy the task.

The teachers were asked if the students had any map reading or had been exposed to world maps on various map projections. The children did not know that the teacher was asked these questions.

Chapter 4

ANALYSIS OF DATA AND RESULTS

Certain criteria were used to decide between 'right' and 'wrong' answers. Considering that the scale is different between maps, and that it changes across individual maps, a radius of correctness was established as roughly 500 earth miles. The radius chosen seemed adequate, for it gave the students 785,000 square miles in which to locate St. Louis, for example. I did not want the radius so large that the correct response area for Los Angeles and San Francisco would be overlapping. This radius was plotted on the answer sheets by comparing map and globe distances for each point. Certain locations had additional criteria. Responses for coastal locations had to be on the coast. Responses for island locations had to be on the island. Responses for interior locations could not be on the coast, even if it was within the 500 mile radius.

After the grading began, there were some responses that were right on the edge of the correct response area so a third (intermediate) category was created, a 'have the right idea but not close enough to be counted' category that included answers between 500 to 800 miles from the actual locations.

Each map for each student was given a score. Each correct answer earned one point. Each near correct answer earned a half point. The total score for each map for each student ranged from 0 to 2 points. The total score for each student is the sum of the scores from all the maps, and it could range from 0 points to 20 points. This total score was used in the statistical analyses for comparing scores between grades.

The distortion on some of the projections made finding certain locations impossible, or nearly so, resulting in approximations or 'not there' answers. For example, the north pole on the conventional Mercator is not on the map. Children were given the option of deciding the location was not on the map or locating it somewhere on the top edge. The option of saying "not there" also provided an out for the students who could not find a location. If a student decided the location was 'not there' and was correct, a point was given, if the student said "not there" and was wrong, no point was given.

The raw and percentage scores for individual students are listed in Table 2. Numbers correct (out of 20 possible) ranged from 0 - 11.5 (0 - 57.5%) for second graders, .5 - 16.5 (2.5 - 82.5%) for fourth graders, and 0 - 20 (0 - 100%) for sixth graders. Medians are 2, 7.5, and 13 respectively.

TABLE 2: RAW AND PERCENT SCORES OF EACH STUDENT

2nd grade	%	4th grade	%	6th grade	%
0.0	0.0	0.5	2.5	0.0	0.0
0.0	0.0	0.5	2.5	2.5	12.5
0.0	0.0	1.0	5.0	2.5	12.5
0.0	0.0	1.0	5.0	3.0	15.0
1.0	5.0	1.5	7.5	3.5	17.5
1.0	5.0	1.5	7.5	5.0	25.0
1.0	5.0	2.0	10.0	5.0	25.0
1.0	5.0	2.5	12.5	7.0	35.0
1.0	5.0	3.0	15.0	9.5	47.5
1.5	7.5	3.5	17.5	11.0	55.0
1.5	7.5	3.5	17.5	11.0	55.0
1.5	7.5	3.5	17.5	11.0	55.0
1.5	7.5	4.0	20.0	11.0	55.0
1.5	7.5	4.0	20.0	11.0	55.0
1.5	7.5	4.0	20.0	11.5	57.5
1.5	7.5	5.5	27.5	12.0	60.0
2.0	10.0	6.5	32.5	13.0	65.0
2.0	10.0	7.0	35.0	13.0	65.0
2.5	12.5	8.0	40.0	13.0	65.0
3.0	15.0	8.0	40.0	13.0	65.0
3.0	15.0	8.5	42.5	13.5	67.5
3.0	15.0	9.0	45.0	13.5	67.5
4.0	20.0	9.5	47.5	13.5	67.5
4.0	20.0	10.0	50.0	14.0	70.0
4.5	22.5	11.0	55.0	14.5	72.5
4.5	22.5	11.0	55.0	15.0	75.0
5.5	27.5	11.5	57.5	15.0	75.0
6.0	30.0	11.5	57.5	16.0	80.0
7.5	37.5	13.0	65.0	17.0	85.0
7.5	37.5	13.0	65.0	17.0	85.0
10.0	50.0	14.0	70.0	17.5	87.5
10.5	52.5	14.0	70.0	17.5	87.5
11.0	55.0	14.5	72.5	18.0	90.0
11.5	57.5	15.0	75.0	18.5	92.5
		15.0	75.0	18.5	92.5
		16.5	82.5	19.0	95.0
				19.5	97.5
				19.5	97.5
				20.0	100.0

The Kruskal-Wallis analysis of variance was used to test the hypothesis of no difference between grades. The Kruskal-Wallis has the advantage of being distribution-free and is suitable for small as well as large sample sizes. The scores that were used were the number correct for each student. The results were significant ($p = .001$). Therefore, the null hypothesis of no difference is safely rejected. There is a significant difference between the grades, in ability to find globe locations on map projections.

As to whether there is a cognitive cliff, it is fairly apparent there is not, (for the groups as a whole). Fourth graders improved by 20.1% (37.2% - 17.1%) over second graders and sixth graders by 25.1 % (62.3% - 37.2%) over fourth graders. Two Mann-Whitney U tests, which are used for comparing two independent samples, resulted in significant differences for both pairs of grades ($p = .000$).

Table 3: SCORES OF STUDENTS BY GRADE

	Number	Scores(Percent)	Total Possible	Student Mean
2nd gr	34	116.5(17.1)	680	3.43
4th gr	36	268 (37.2)	720	7.44
6th gr	39	486 (62.3)	780	12.46

To test for significant differences between map projections, the Kruskal-Wallis test was used. The scores that were used were the percent correct for each student, by map, for each grade. The result was the non-rejection of the null hypothesis ($p = .99$); there is no significant differences between the maps.

The finding of no difference between projections is particularly interesting because one would expect the most globe-like projections (orthographic) to be easier to use. Students learn about the globe in second grade, but they do not study small scale maps until fifth or sixth grade in these school systems. One can speculate that the Mercator fares well because it is a map many children still see in classrooms. The more unusual projections were ranked the hardest and a large enough sample of students may show that a real difference does exist.

The Kruskal-Wallis was also used to check for significant differences in difficulty between the places the students were asked to locate. The results showed that the null hypothesis cannot be rejected; ($P = .4$) the locations are not significantly different from one another.

To test whether the coastal locations, taken as a group, were easier than the interior ones, the Mann-Whitney U test was used. The results show that the null hypothesis cannot be rejected; the coastal locations are not significantly easier than the interior ones. The test was run leaving out the North Pole and Hawaii because they really cannot be classified as interior or coastal.

A Mann-Whitney U test was run comparing North and South America against the rest of the world. The difference was significant (p=.01) for a one-tailed test, implying that locations in North and South America were easier. It is easy to understand why students are more familiar with North and South America, having studied them in school, and South America is an easy shape to recognize. South America's location astride the equator also means that on most of the projections it had little distortion.

One of the questions asked at the end of the test was whether the student thought any of the maps and places were 'hard'. The student and I went back through the maps to identify the difficult maps or locations. If the student identified the map as hard or both of the locations on the map as hard, then the map was given a point for "difficulty". If the student said that only one of the two locations on the map was hard, it was given half a point. The scores were added up for each map; the maps were then ranked from least difficult to most difficult.

Kendall's correlation coefficient t (tau) is a distribution-free statistic that can be used with small samples to measure correlation. I used it to compare the student location scores with the score for difficulty for each map. There was a significant (p=.036) inverse relationship between the number right for each map and the number of students that labeled the map 'hard'. The result suggests that students recognized when they were making errors or having difficulties in general.

The teachers informed me of map skills studied by the children. The second graders had seen a globe and should know it is a model of the earth. Most of the fourth graders had some instruction about the globe and about latitude and longitude. Many of the classes study their state (Michigan) in fourth grade. The sixth graders were studying continents, usually South America. The information suggests that classroom activities do influence performance on the very specific task in the study.

OTHER RESULTS

The answers to the questions that came after the test cannot be analyzed statistically. Not all students responded, the answers were subjective, and I sometimes prompted students or helped them put their ideas into words. The information is, nonetheless, useful in understanding how children approached the task. The answers to these questions are given as a percent by grade in Tables 4 through 8 below.

The students were asked "How did you know that _________ was right?" For this question I first went through the test booklet to find a correct answer, then showed it to the student and asked how they knew that location was there. If there was no immediate response, I prompted them by asking if they used shape, or latitude and longitude, or some other means of finding the place. The results (percentage by grade) are shown in Table 4.

Table 4: Reasons For Correct Answer (in percentage)

	Shape	Lat. & Long.	Other	None
2nd gr.	50	11.8	26.5	11.8
4th gr.	69.4	0	22.2	8.3
6th gr.	69.2	12.8	17.9	0

The answer 'none' means they either had no correct answers or no response to the question. 'Other' responses were specific, for example, using the north pole for a reference point or recognizing that the location is an island or on the coast. Additional responses for 'other' were from students recognizing a specific location, for example: Africa, Sri Lanka, India. One second grader turned the booklet around so that the maps had north at the bottom and had no concept of figure ground, i.e., could not tell ocean from land even though the oceans had grid lines and the land did not. Another second grader made up his own imaginary, randomly-spaced grid on the globe and counted down from the north pole on this grid to the locations on the globe, and then counted down the same amount on the map. I saw several students use this technique using the north pole, Soviet Union and other reference points. This procedure is reminiscent of what was observed by Piaget, Inhelder and Szeminska (1960), who reported that many children set up their own coordinate systems when measuring objects or locating positions.

The fourth graders used a wider variety of clues to find locations, such as the continents of Africa and South America, rivers, or a particular country or state (such as the U.S., India, the U.S.S.R., or Michigan). Although most of the fourth graders had received some instruction on the globe and latitude and longitude, none of them said they used the graticule to find locations.

Not surprisingly, the sixth graders were the most sophisticated in their use of references to locate places. They used the Great Lakes, rivers, continents such as North America, specific countries such as Brazil and the U.S., and specific features such as an island or an isthmus. Two students answered the question by simply saying that they used the position on the globe to find the location on the map, not a very revealing answer. Another sixth grader however, had no idea what the task was about. At the other end of the spectrum was a student who told me he had made a globe and plays games using maps. A few students used the graticule to locate places.

I cannot explain why the fourth graders did not use latitude and longitude to locate places whereas some second and sixth graders did. Since most of the students do not learn about latitude and longitude until fourth grade, their score could be correct. The second graders' score may be misleading because it could refer to self-made grids or an arbitrary answer to a question they did not understand.

The students were asked about their exposure to maps. First, they were asked what maps they had seen in school, then what maps they had at home. The results are presented in Tables 5 and 6.

Table 5: School Maps (in percentage)

	Globe	World	U.S.	Michigan	City	Road
2nd gr.	97.1	67.6	76.5	82.4	44.1	26.5
4th gr.	100.0	94.4	97.2	97.2	83.3	41.7
6th gr.	84.6	97.4	94.9	82.1	56.4	66.7

The question was phrased 'What maps have you seen in school?' I assumed the answer would cover all the years the students had been in school, but the responses look as though they answered for just the present year. With the revised assumption in mind, the results in Table 5 show that the fourth graders have more contact with maps (except road maps) than the other students, possibly because the most intense study of maps is in this grade. If my original assumption was correct, perhaps sixth graders had not had the same curriculum in previous years.

Table 6 shows the results concerning maps in the home. It is possible that the responses for 'atlas' overlap the responses for 'road maps' because the atlas could be a road atlas. I explained to the students only that an atlas was a book of maps. Possibly, some of the high values among the second graders, such as 17.6% for world maps compared to the values of 2.8% and 5.1% for the other grades, could be because the younger children are saying 'yes' just to be agreeable and are not understanding what is being asked. Except for world maps and road maps, the fourth and sixth graders have more maps at home than the second graders, or are at least more aware of them.

Table 6: Home Maps (in percentage)

	Globe	World	U.S.	Road	Atlas	None
2nd gr.	32.4	17.6	2.9	88.2	44.1	5.9
4th gr.	41.7	2.8	5.6	72.2	52.8	0
6th gr.	41.0	5.1	7.7	56.4	56.4	0

The students were also asked "Have you ever looked at maps on your own, not because you have to and not for school, but just for fun?" (Table 7). The answers they had to chose from were: often, once in a while, or never. The students used their own definitions of those responses in answering. They were assured that answering 'never' was a good answer if it was true.

Table 7: Reading Maps For Fun (in percentage)

	Often	Once in a while	Never
2nd gr.	11.8	82.4	5.9
4th gr.	30.6	63.9	2.8
6th gr.	10.3	61.5	5.1

There can be no real comparison between grades because 'once in a while' to a second grader might be 'often' to a sixth grader or vice versa. But based on the children's own perceptions, the fourth graders seem to use maps more often and enjoy them more.

The last question asked was if the students thought maps were fun. (Table 8) This question is important because it is really asking if they like maps, if maps hold their interest. Perhaps if the children like maps they will learn something from them. This question was presented to draw a yes or no response but other answers were accepted. The category of 'sometimes' includes responses such as 'kinda' and 'sorta.' Some of the children answered that they thought maps were hard. The total percentage by grade can be greater than 100% because those that answered 'no' could also have answered 'hard.'

Table 8: Maps Are Fun (in percentage)

	Yes	No	Sometimes	Hard
2nd gr.	85.3	5.9	5.9	0
4th gr.	83.3	11.1	2.8	2.8
6th gr.	64.1	7.7	25.6	7.7

Tables 7 and 8 show a decline from 2nd to 6th grade in their interest in maps. There is a strong change in enjoyment of maps among the sixth graders. This decline could result from their becoming used to seeing maps, and, therefore, the maps become more commonplace and less exciting. It could also be that as the maps become more complex, and the students are forced to use them more, they are becoming less appealing. Another possibility is (again) that younger children may be trying to please the questioner.

Chapter 5

SUMMARY AND CONCLUSIONS

The Kruskal-Wallis test supports the hypothesis that the performance of the students using map projections will improve as the grade level increases.

Piaget (1956) states that the development of a child's ability is a continuous process. The results of this study imply a continuous progression in the development of skill over the grades covered and, in this sense, parallel Piaget's findings. I had thought I might see a dramatic change of ability at a specific level of development, a cognitive cliff between a pair of grades. There may well be such a cliff within individuals, but, if so, it does not come at the same age level for every child. Overall scores increased both from second to fourth grade and from fourth to sixth, and there were some children in second grade that did very well whereas some sixth graders had very low scores. It would be interesting to run the test again for 3rd, 4th, and 5th graders, to see if there are significant differences between students that are closer in levels of development. Even more interesting would be studies of individual children over a span of time.

Piaget shows that the development of a child's ability to grasp the concept of visual realism or perspective should be at age nine or ten, about fourth grade. In this study, the fourth graders (generally 9 year olds) had a median score of less than half the answers correct. The sixth graders (generally 11 year olds) had a median score of about two thirds correct. These results suggest that the ability to deal with locational correspondence from globe to map is developing somewhat later than the general ability with perspective and that the task they had to do required something more or something different than just a grasp of perspective.

It was evident by their scores and their responses that three sixth graders had not developed the ability to do the test successfully. One of them (with a score of zero) placed all the locations at the intersection of latitude and longitude lines. Another put all of the locations on the coast, and the third responded "not there" for most of the locations. These students were in regular classes so they can be considered to have normal mental abilities, but it appears that they have not developed the ability to see the correspondence of globe locations and map locations. It is possible that some people never develop this ability.

My results also give some degree of credence to Renner (1951) and Miller (1985) who stated that children should not be taught about maps until sixth grade. Even though the fourth graders had some instruction on the globe and latitude and longitude, they did not use these concepts consciously to help find the locations on the maps. "Exposure to maps fosters but fails to ensure geographical knowledge or the ability to comprehend information presented on maps" (Boehm and Petersen 1987, p. 167). It is possible, however, that it just takes a lot of practice and exposure before children can use world maps effectively. In that case, starting earlier is not only justified but essential. It is also important to realize that map concepts range widely in difficulty, and teachers vary map activities according to level of readiness from one grade to another. Even if world maps cannot be used effectively until later, exposure to local maps (maybe even to world maps despite hazy understanding) is probably paving the way to that effective use of world maps.

One way of testing whether early exposure of maps is useful would be to follow two groups of students from the beginning of schooling to at least sixth grade. One group would be exposed to maps frequently in each grade and the other would not. Students would be given some simple map tests to see if there is any difference between the groups.

A simpler and more feasible way would be to test children, try to teach them relevant skills, and then test them again to see if they have improved. Starting at perhaps kindergarten, I would progress through the grades until I reached the level in which the children learned the information and could use it on the test.

Home environment, as well as individual interests and mental development could influence differences among students within the same grade. I observed that the inner-city students had a harder time with the test, and that students who came from other countries did better than their American classmates, although I did not collect systematic information on those variables. The only information received about the students' home life was what kinds of maps they have at home. It would be interesting to check systematically the students' social and economic background to see if those factors correlate with their abilities and how closely.

The secondary hypotheses questioned the range of difficulty of the projections and locations. Neither was statistically significant. Therefore the only differences among the students were due to the grade level.

I had anticipated that interior locations would be more difficult than the coastal ones, but results did not show that to be so. A common error that the students made was to place a coastal location on a different coast. This shows that at least they could recognize land and water even if they could not accurately match shapes. However, they did find western hemisphere locations easier than others.

Some interesting, if somewhat peripheral, questions are raised by this study. If children as young as six can use a grid, why is latitude and longitude such a difficult concept? Are fourth graders really getting more map instruction in school than the second and sixth graders? Why do the older students feel that maps are harder and less fun then the younger students do? Are the students losing interest in maps as they get older and, if so, why?

As an elementary skill necessary for the use of small scale maps, the task in this study has implications for readiness to use maps of extensive regions of the earth's surface in the normal educational setting. This study does not give a precise answer to when children can use map projections, but at least it does indicate that considerable development of the skill takes place between second and sixth grades.

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APPENDIX A

This appendix has the working materials used to carry out the testing.

This is the list of places that the students located on the maps. For each place I pointed to the location on the globe, gave the place name, and a one sentence discription similar to what is in parentheses below. Keeping my pointer on the globe location, I then repeated the place name. The brief discription was to keep the children from being bored by the task. The discriptions do not contain any locational clues.

There are two places for each map, one coastal and one continental. The list is in order according to the map order.

Map A Moscow (Moscow is a very large city we often hear about in the news)
Singapore (Singapore is a city where many countries come to trade goods)

Map B San Francisco (San Francisco is known for having earthquakes.)
Manaus (Manaus is a city located in a jungle.)

Map C Reykjavik (Reykjavik is known as the city of fire and ice.)
Xian (Xian is a city that is thousands of years old.)

Map D North Pole (The North Pole was reached by dogsled recently.)
Cape Town (Cape Town was found by explorers going to the orient.)

Map E Cape Adare (The first persons set foot here in 1895.)
Hawaii (Hawaii is popular with tourists.)

Map F Lake Victoria (Lake Victoria is on the border of three countries.)
Godthab (Godthab has very short days in the winter.)

Map G Auckland (Many sheep go to market in Auckland.)
Paris (Paris is city with many museums.)

Map H Gibralter (Gibralter is known for a large rock cliff.)
La Paz (Volcanoes can be seen from the city of La Paz.)

Map I Anchorage (Anchorage is a city near the base of a glacier.)
Kathmandu (Kathmandu is probably the highest city in the world.)

Map J St. Louis (St. Louis has a monument which is a giant arch that people can go into.)
Jerusalem (Jerusalem is considered a holy city to three religions.)

These are the questions I asked the students during the test.

Which points did you think were hard?_______________

____

What have you done with maps in school?_____________

____

What maps do you have at home?______________________

____

How did you know _____________________ was correct?

____

____

Do you think maps are fun?__________________________

Do you read maps just for fun?______________________

APPENDIX B

This appendix shows the raw scores for each individual student by grade, map, and location.

TABLE 9: SECOND GRADE RAW SCORES BY MAP AND LOCATION

	ORTHOGRAPHIC CONVENTIONAL	ORTHOGRAPHIC OBLIQUE	GNOMONIC PIECEWISE	LAMBERT POLAR	GOODE'S INTERRUPTED HOMOLOSINE	MERCATOR CONVENTIONAL	CONFORMAL IN A SQUARE	TRANSVERSE MERCATOR	OBLIQUE OVAL	INTERRUPTED WITH CONTINENTAL SPLIT	TOTAL
Moscow	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	2.0
Singapore	1.0	0.0	0.0	0.0	0.0	1.0	1.5	0.0	0.0	0.0	3.5
San Francisco	0.0	1.5	0.0	0.0	0.0	0.5	1.5	0.0	1.0	0.0	4.5
Manaus	0.0	1.5	0.0	0.0	2.0	1.0	2.0	2.0	2.5	0.5	11.5
Reyjavik	0.0	3.0	0.0	0.0	0.0	1.0	1.0	0.0	1.0	1.0	7.0
Xian	2.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	4.0
North Pole	3.0	2.0	3.0	1.0	0.0	0.0	3.0	3.0	3.0	2.0	20.0
Cape Town	1.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	1.0	1.0	5.0
Cape Adare	0.0	1.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
Hawaii	1.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	1.0	2.5
Lake Victoria	0.0	0.0	1.0	0.0	0.5	1.0	0.0	0.0	0.5	0.0	3.0
Godthab	1.0	1.0	0.0	0.0	0.5	1.0	0.0	0.0	0.0	0.0	3.5
Auckland	0.0	0.5	1.0	2.0	0.0	1.5	0.0	0.0	0.0	2.0	7.0
Paris	0.0	0.0	0.0	1.5	1.0	1.0	0.0	0.0	1.0	0.0	4.5
Gibraltar	0.0	0.0	0.0	0.0	2.0	0.0	1.5	0.0	0.0	0.0	3.5
La Paz	2.5	0.5	1.0	0.5	2.0	1.0	1.0	0.5	0.0	0.0	9.0
Anchorage	0.0	0.0	1.0	0.0	2.0	2.0	0.5	1.0	0.0	0.0	6.5
Kathmandu	0.0	0.0	0.0	0.0	1.0	2.0	0.0	0.0	0.0	0.0	3.0
St. Louis	0.0	0.0	1.0	1.5	1.5	1.0	2.0	0.5	0.0	0.0	8.0
Jerusalem	0.0	0.0	0.0	0.0	0.0	1.5	1.0	0.0	0.0	1.0	3.5
TOTAL	11.5	11.0	8.0	13.0	12.5	16.5	16.5	7.5	11.0	8.5	116.5

TABLE 10: FOURTH GRADE RAW SCORES BY MAP AND LOCATION

	ORTHOGRAPHIC CONVENTIONAL	ORTHOGRAPHIC OBLIQUE	GNOMONIC PIECEWISE	LAMBERT POLAR	GOODE'S INTERRUPTED HOMOLOSINE	MERCATOR CONVENTIONAL	CONFORMAL IN A SQUARE	TRANSVERSE MERCATOR	OBLIQUE OVAL	INTERRUPTED WITH CONTINENTAL SPLIT	TOTAL
Moscow	0.0	0.0	2.5	0.5	2.0	1.0	0.0	1.0	2.0	0.0	9.0
Singapore	0.0	3.0	1.0	0.0	2.5	2.0	0.0	0.0	1.0	0.0	9.5
San Francisco	2.0	1.5	1.0	4.5	2.0	3.0	2.0	1.0	0.0	0.0	17.0
Manaus	2.0	2.0	1.5	3.0	0.0	4.0	2.0	1.0	1.0	1.5	17.0
Reyjavik	0.0	2.0	1.0	1.0	3.0	2.0	3.0	2.0	1.0	0.0	15.0
Xian	2.0	0.0	1.0	1.0	2.0	0.5	0.5	1.0	0.0	0.0	8.0
North Pole	2.0	2.0	3.0	4.0	4.0	3.0	4.0	3.0	3.0	1.0	29.0
Cape Town	1.0	0.0	1.0	0.0	3.5	5.5	2.0	3.0	2.0	0.0	18.0
Cape Adare	0.5	2.0	0.0	1.0	0.0	0.0	2.0	1.0	0.0	2.0	8.5
Hawaii	0.5	0.0	0.0	0.0	1.0	1.5	2.0	0.0	1.0	2.0	8.0
Lake Victoria	0.0	0.0	1.0	0.0	2.0	0.0	2.0	3.5	1.0	1.0	10.5
Godthab	2.0	1.5	0.0	1.0	1.0	1.0	3.0	1.0	2.0	3.0	17.5
Auckland	2.0	3.0	0.0	0.0	1.0	2.0	0.5	0.0	4.0	2.0	15.5
Paris	0.5	1.0	0.0	0.0	1.0	1.0	2.0	1.0	4.5	0.0	11.0
Gibraltar	0.0	2.0	1.0	0.0	0.0	0.0	2.0	1.0	2.0	3.5	11.5
La Paz	2.0	2.0	1.0	2.0	0.0	1.0	1.0	1.0	1.0	4.5	15.5
Anchorage	3.0	2.0	2.0	1.0	0.0	0.0	0.0	1.0	0.0	1.0	10.0
Kathmandu	4.0	1.0	2.0	2.0	1.0	0.0	1.0	1.0	0.0	1.0	13.0
St. Louis	4.5	5.5	0.5	2.5	2.0	0.5	0.0	0.0	0.0	1.0	16.5
Jerusalem	0.0	2.0	0.0	2.5	1.0	0.0	0.0	1.0	2.0	0.0	8.0
TOTAL	28.0	32.5	18.5	26.0	29.0	28.0	29.0	25.5	28.0	23.5	268.0

TABLE 11: SIXTH GRADE RAW SCORES BY MAP AND LOCATION

	ORTHOGRAPHIC CONVENTIONAL	ORTHOGRAPHIC OBLIQUE	GNOMONIC PIECEWISE	LAMBERT POLAR	GOODE'S INTERRUPTED HOMOLOSINE	MERCATOR CONVENTIONAL	CONFORMAL IN A SQUARE	TRANSVERSE MERCATOR	OBLIQUE OVAL	INTERRUPTED WITH CONTINENTAL SPLIT	TOTAL
Moscow	0.0	0.0	2.0	0.5	1.0	2.5	0.0	2.0	2.0	2.0	12.5
Singapore	3.0	1.0	1.0	0.5	2.0	4.0	3.0	1.0	2.0	2.0	20.0
San Francisco	3.0	3.0	2.0	2.0	4.0	2.5	4.0	3.0	3.0	2.0	28.5
Manaus	3.5	3.0	1.0	1.5	4.0	4.0	3.5	4.5	3.5	1.5	30.0
Reyjavik	3.0	3.0	3.0	2.0	1.0	4.0	4.0	5.0	3.0	4.0	32.0
Xian	2.0	2.5	1.0	2.0	1.0	1.5	2.0	2.5	1.0	2.0	17.5
North Pole	4.0	5.0	3.0	3.0	3.0	1.0	4.0	3.0	5.0	2.0	32.0
Cape Town	1.0	0.5	2.0	2.0	2.5	1.5	4.0	2.5	3.5	2.0	21.5
Cape Adare	1.0	3.0	2.0	2.5	3.0	1.5	2.0	1.5	1.0	3.0	20.5
Hawaii	1.5	4.0	1.0	3.0	1.0	2.0	1.0	2.5	3.0	5.0	24.0
Lake Victoria	3.0	2.0	3.0	1.5	2.0	2.0	2.5	1.0	3.0	3.0	23.0
Godthab	3.0	4.5	3.0	2.0	3.0	3.0	3.0	2.0	3.5	2.0	29.0
Auckland	3.0	5.0	1.0	1.0	4.0	3.0	1.0	1.5	2.0	4.0	25.5
Paris	1.0	2.5	1.0	4.0	2.0	3.0	3.0	1.5	2.0	3.0	23.0
Gibraltar	2.0	1.0	2.0	3.0	4.0	2.0	3.0	2.0	2.0	2.0	23.0
La Paz	4.0	2.0	3.5	2.0	1.5	2.5	3.0	3.0	2.0	1.0	24.5
Anchorage	0.0	2.0	1.5	4.0	3.0	3.5	3.5	3.0	3.0	2.0	25.5
Kathmandu	2.0	3.0	2.5	2.5	3.0	2.0	1.0	3.0	2.0	2.0	23.0
St. Louis	3.0	2.0	4.0	3.0	5.0	3.5	4.0	3.0	3.0	3.0	33.5
Jerusalem	1.0	0.5	0.0	3.0	2.5	3.0	2.5	1.0	3.0	1.0	17.5
TOTAL	28.0	32.5	18.5	26.0	29.0	28.0	29.0	25.5	28.0	23.5	486.0

APPENDIX C

This appendix shows the map projections with the students wrong and near right answers shown with lines connecting them to the correct locations. Each map is labeled with the projection name and grade represented. The correct locations are labeled with a letter or letters shown in the list below. Some of the maps shown were reduced somewhat from the originals shown to the students. Originals were on 8 1/2 x 11 paper but were not necessarily within the 6 x 9 format used here.

Mo	Moscow, U.S.S.R.
S	Singapore
SF	San Francisco, CA
M	Manaus, Brazil
R	Reykjavik, Iceland
X	Xian, China
N	North Pole
C	Cape Town, South Africa
CA	Cape Adare, Antarctica
H	Hawaii
LV	Lake Victoria, Africa
G	Godthab, Greenland
Au	Auckland, New Zealand
P	Paris, France
Gi	Gibraltar
L	La Paz, Bolivia
A	Anchorage, AK
K	Kathmandu, Nepal
ST	St. Louis, MO
J	Jerusalem, Israel

LIST OF FIGURES IN APPENDIX C

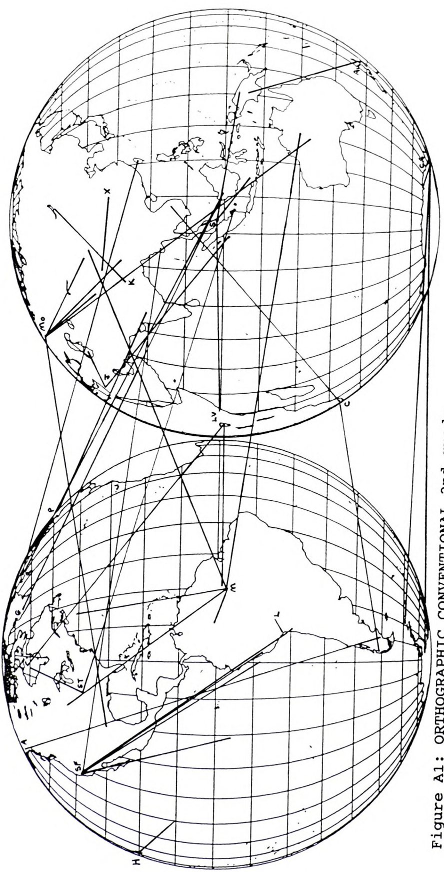

Figure A1: ORTHOGRAPHIC CONVENTIONAL 2nd grade

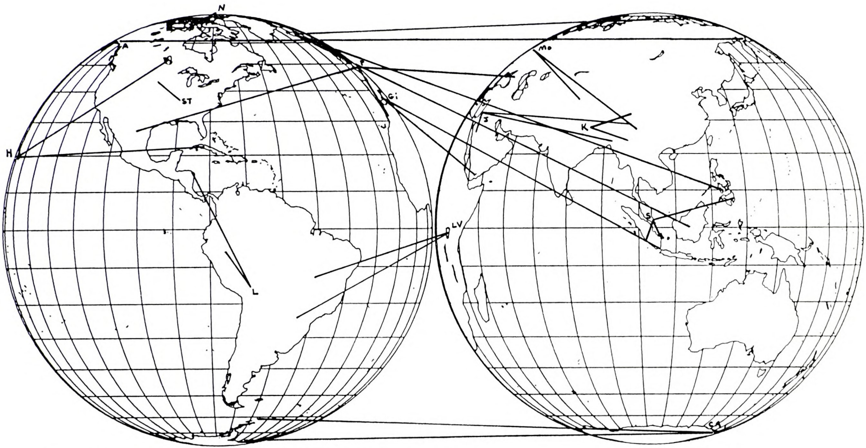

Figure A2: ORTHOGRAPHIC CONVENTIONAL 4th grade

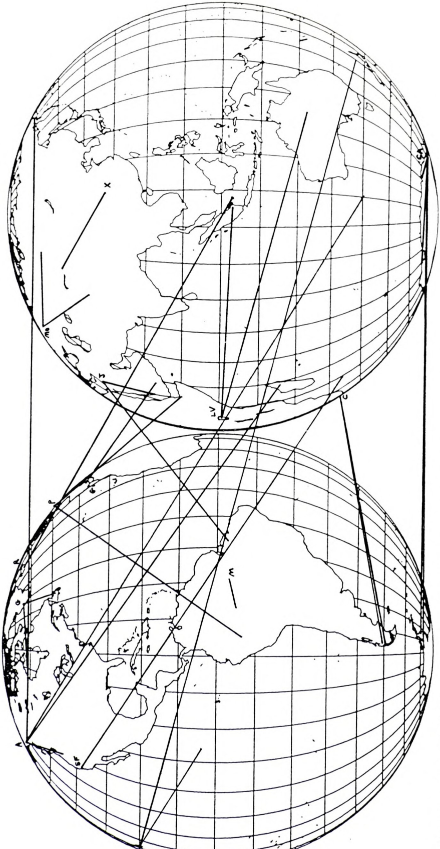

Figure A3: ORTHOGRAPHIC CONVENTIONAL 6th grade

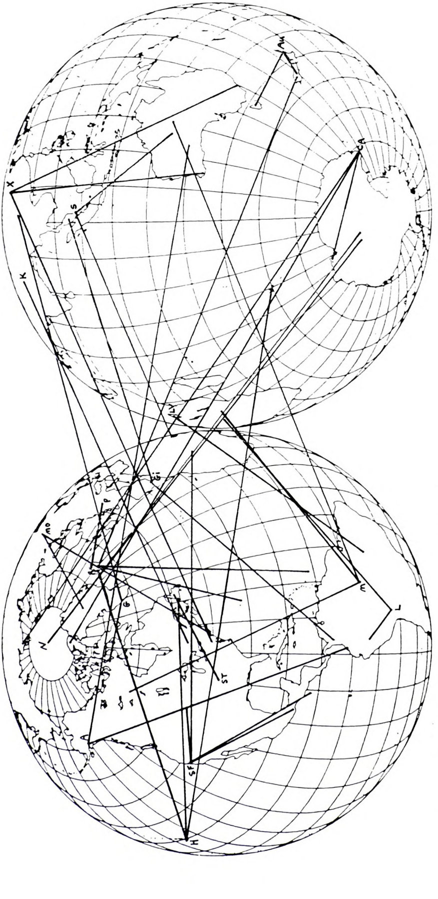

Figure B1: ORTHOGRAPHIC OBLIQUE 2nd grade

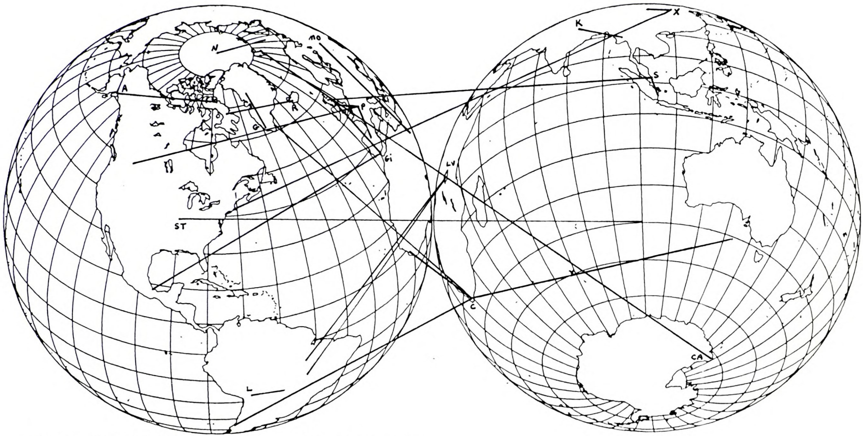

Figure B3: ORTHOGRAPHIC OBLIQUE 6th grade

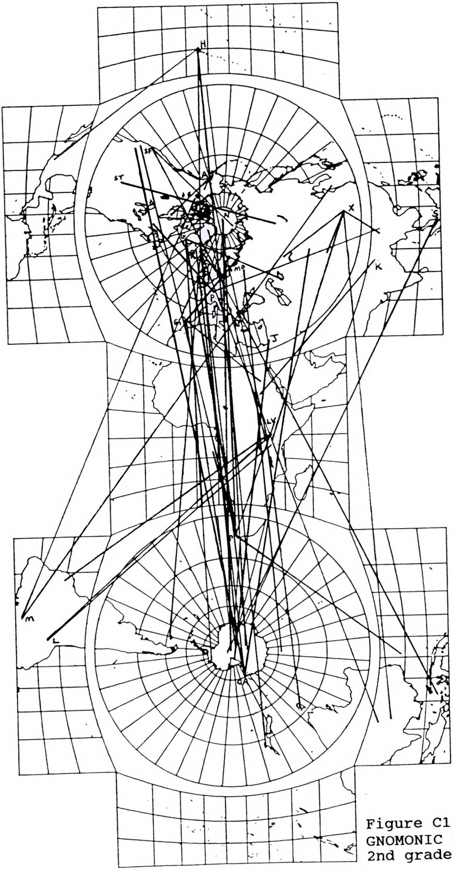

Figure C1:
GNOMONIC PIECEWISE
2nd grade

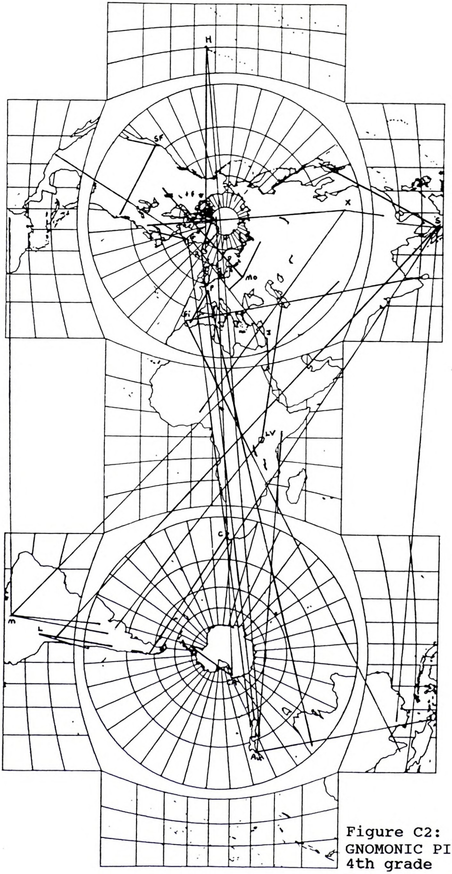

Figure C2:
GNOMONIC PIECEWISE
4th grade

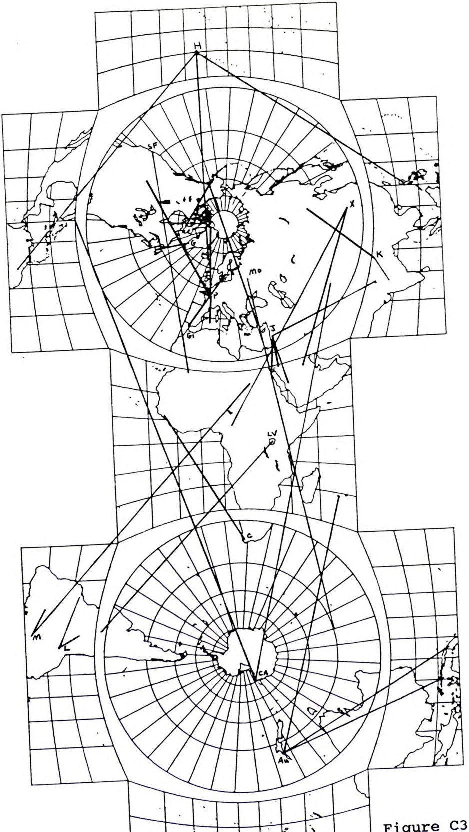

Figure C3:
GNOMONIC PIECEWISE
6th grade

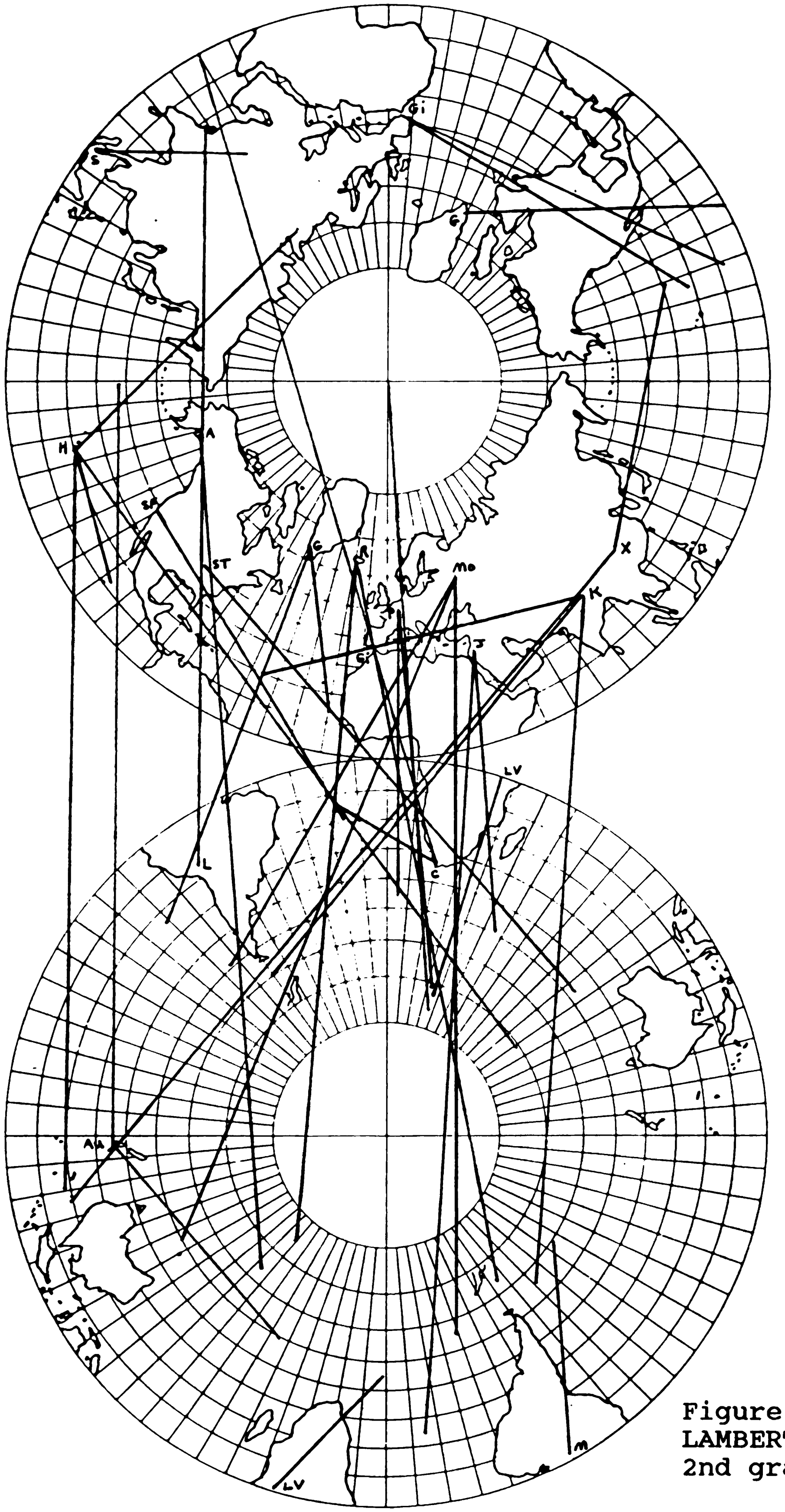

Figure D1:
LAMBERT POLAR
2nd grade

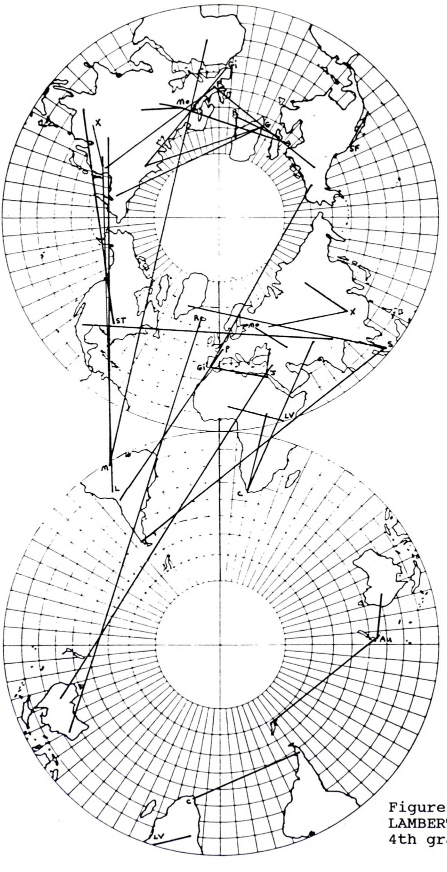

Figure D2:
LAMBERT POLAR
4th grade

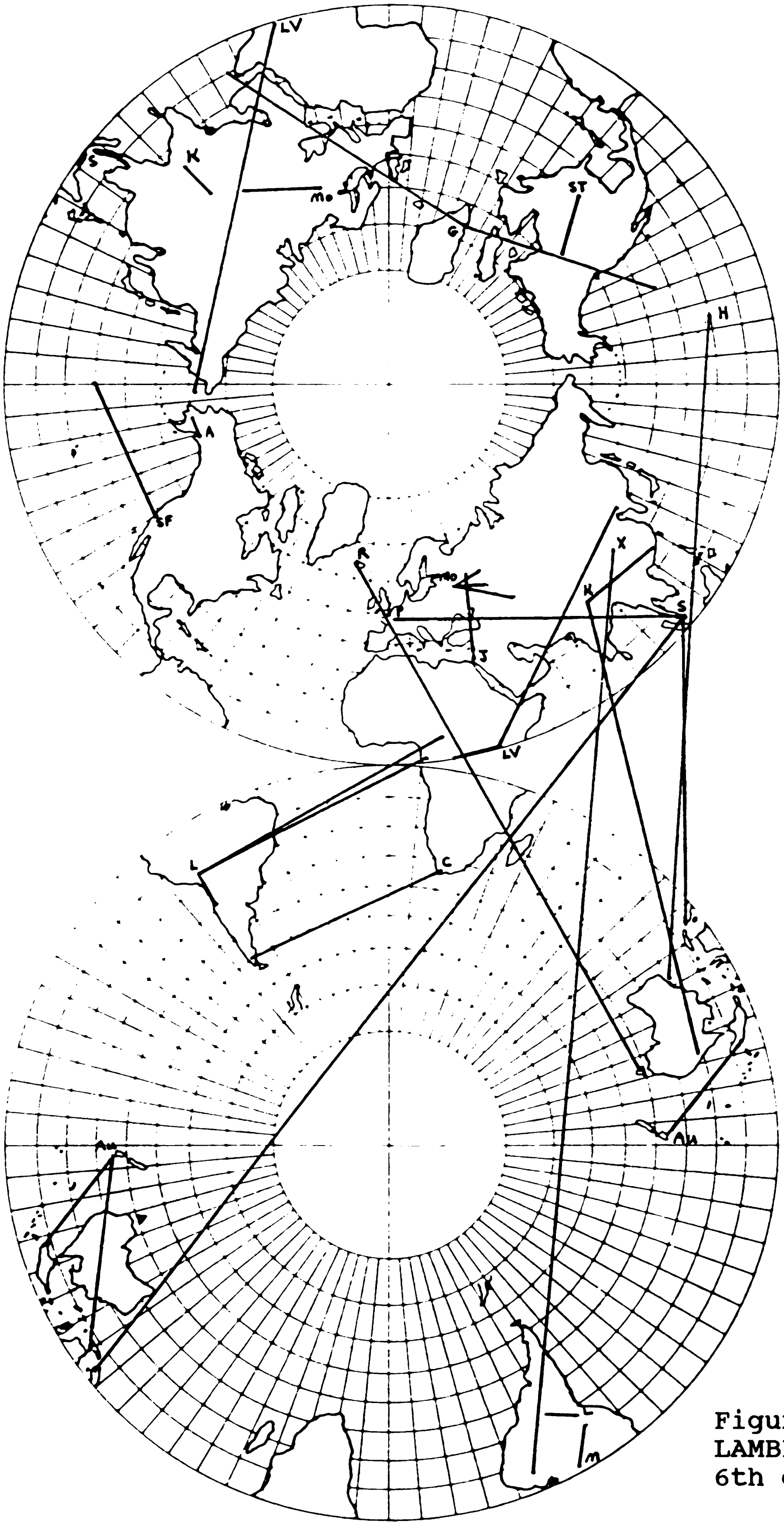

Figure D3:
LAMBERT POLAR
6th grade

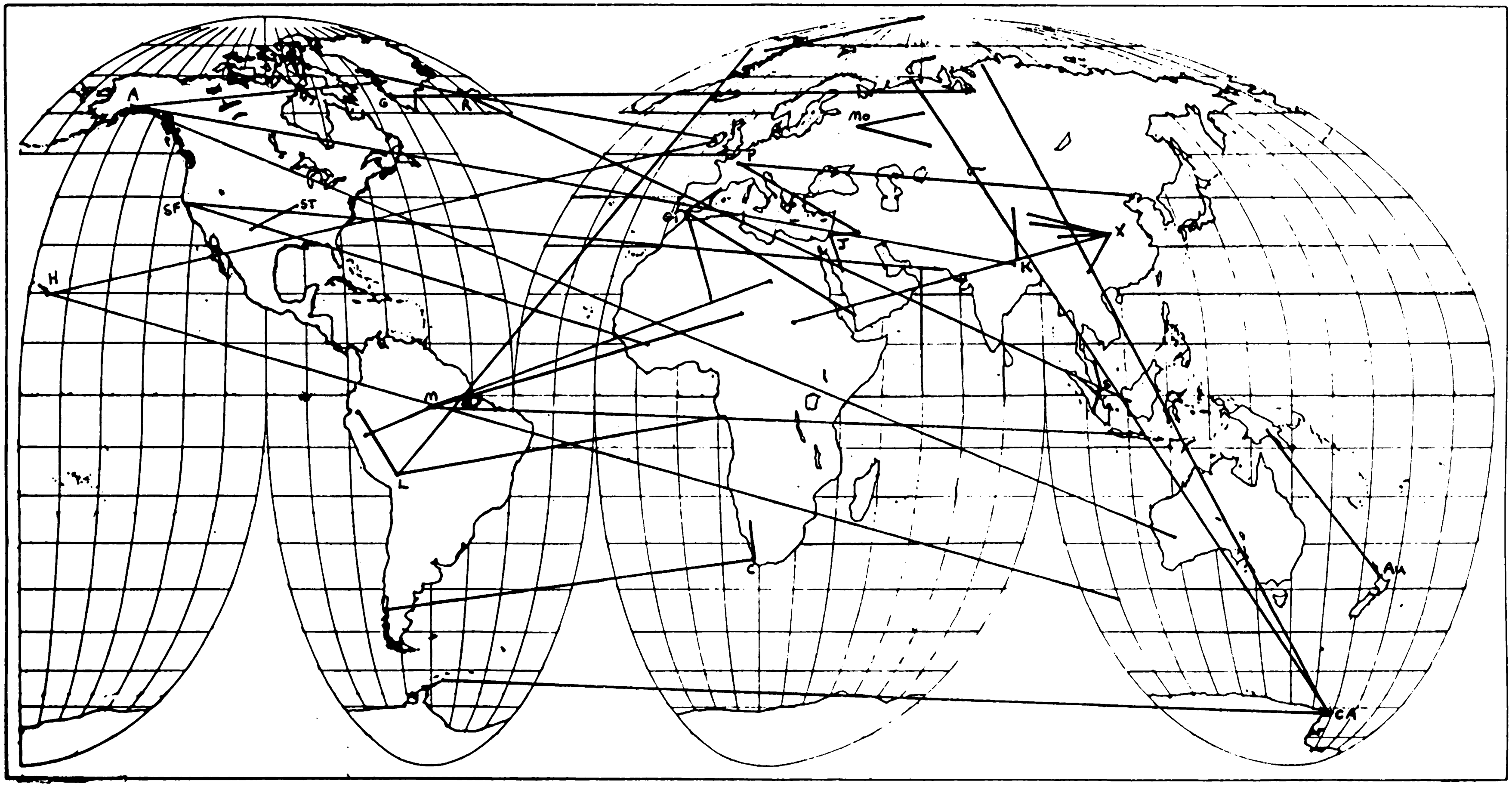

Figure E2: GOODE'S INTERRUPTED HOMOLOSINE 4th grade

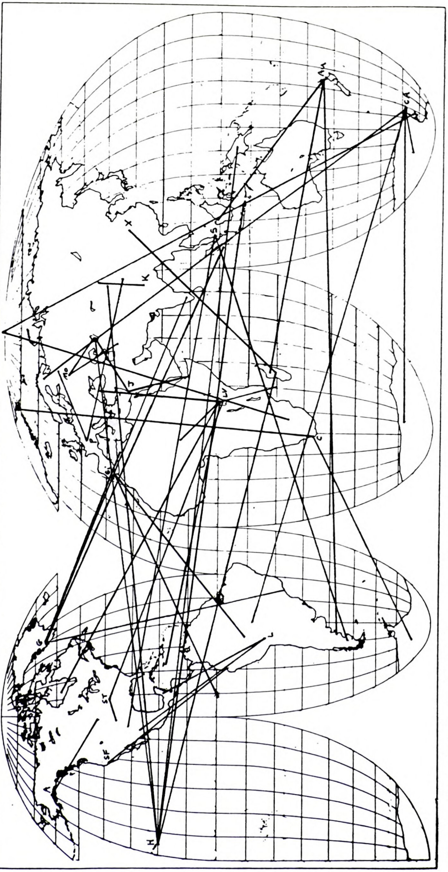

Figure E1: GOODE'S INTERRUPTED HOMOLOSINE 2nd grade

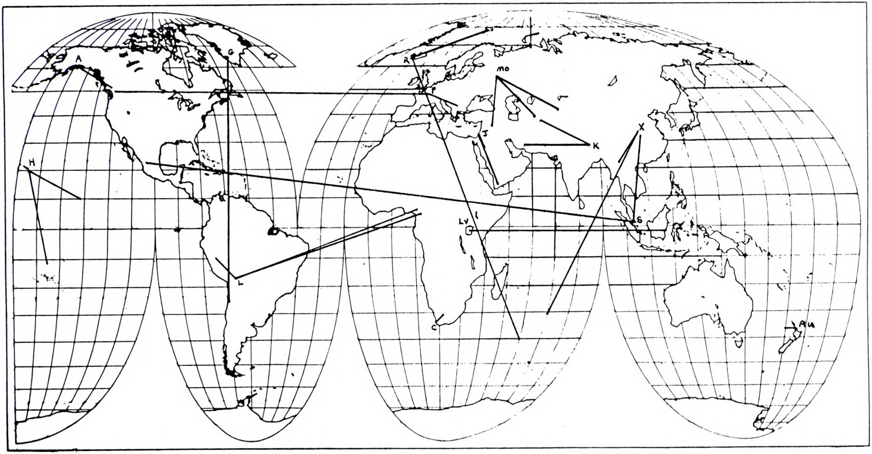

Figure E3: GOODE'S INTERRUPTED HOMOLOSINE 6th grade

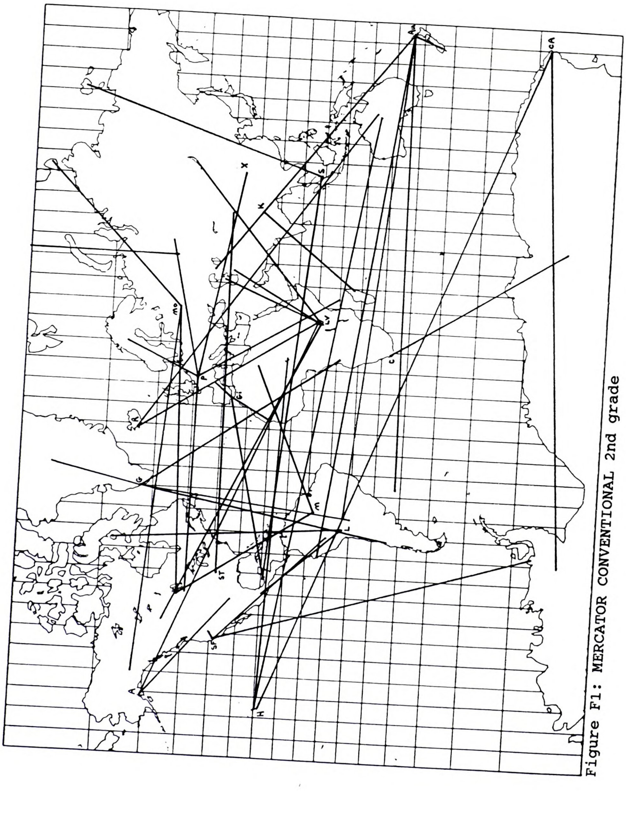

Figure F1: MERCATOR CONVENTIONAL 2nd grade

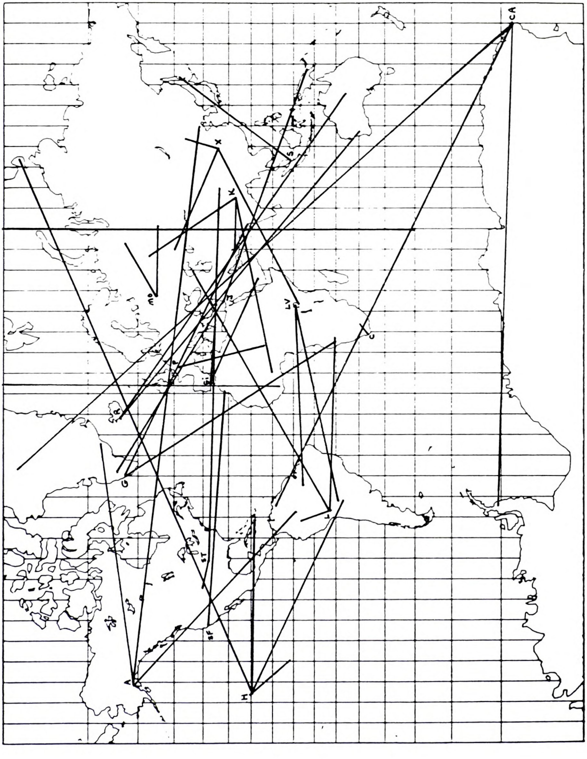

Figure F2: MERCATOR CONVENTIONAL 4th grade

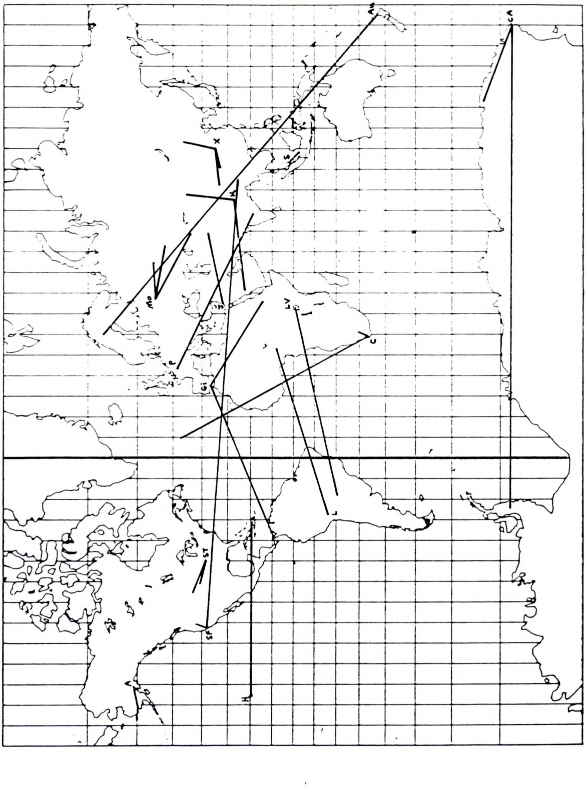

Figure F3: MERCATOR CONVENTIONAL 6th grade

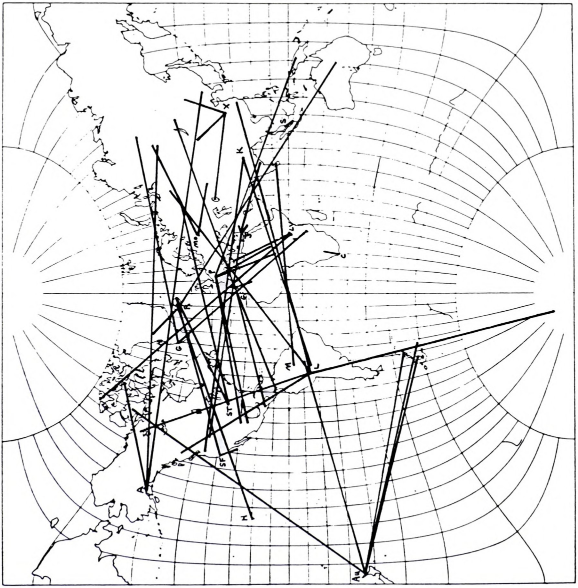

Figure G1: CONFORMAL IN A SQUARE 2nd grade

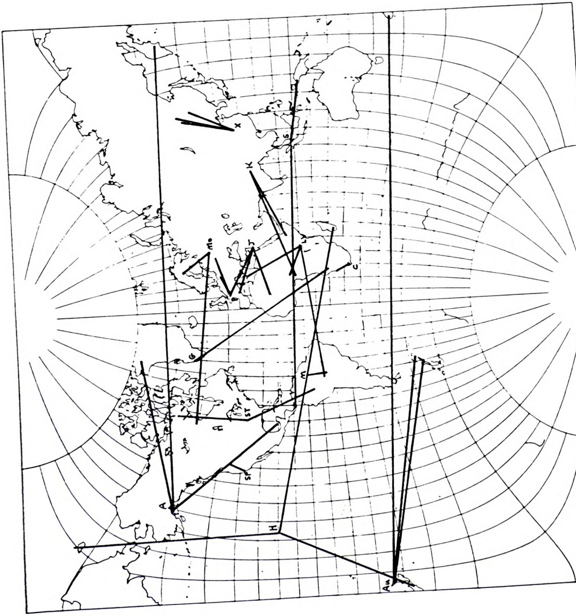

Figure G2: CONFORMAL IN A SQUARE 4th grade

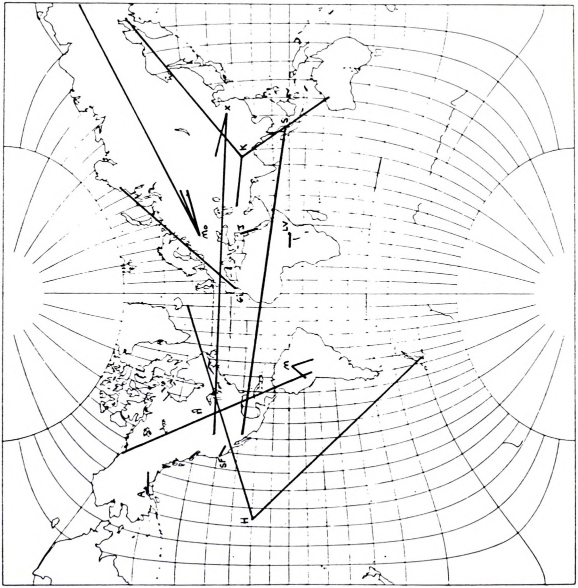

Figure G3: CONFORMAL IN A SQUARE 6th grade

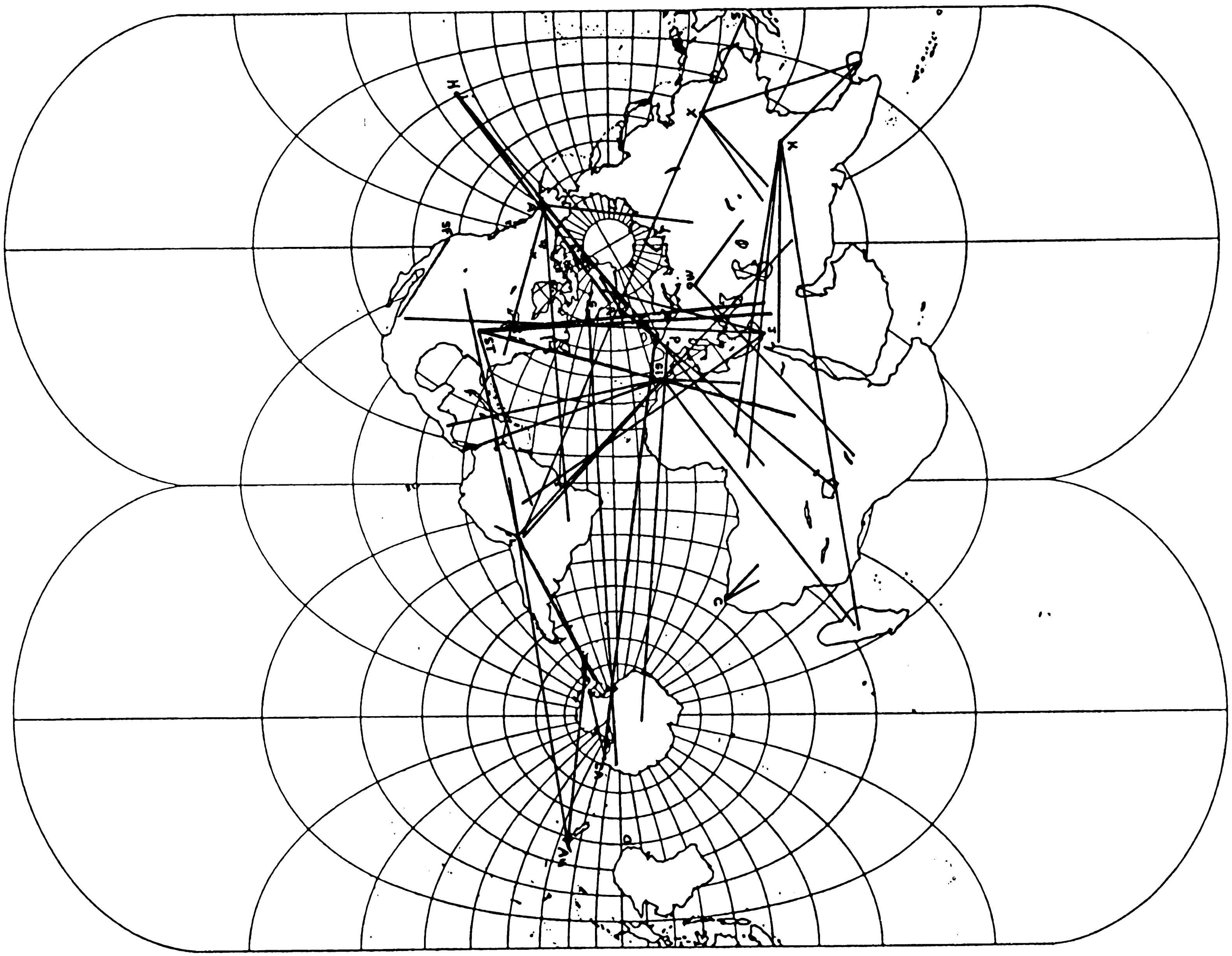

Figure H1: TRANSVERSE MERCATOR 2nd grade

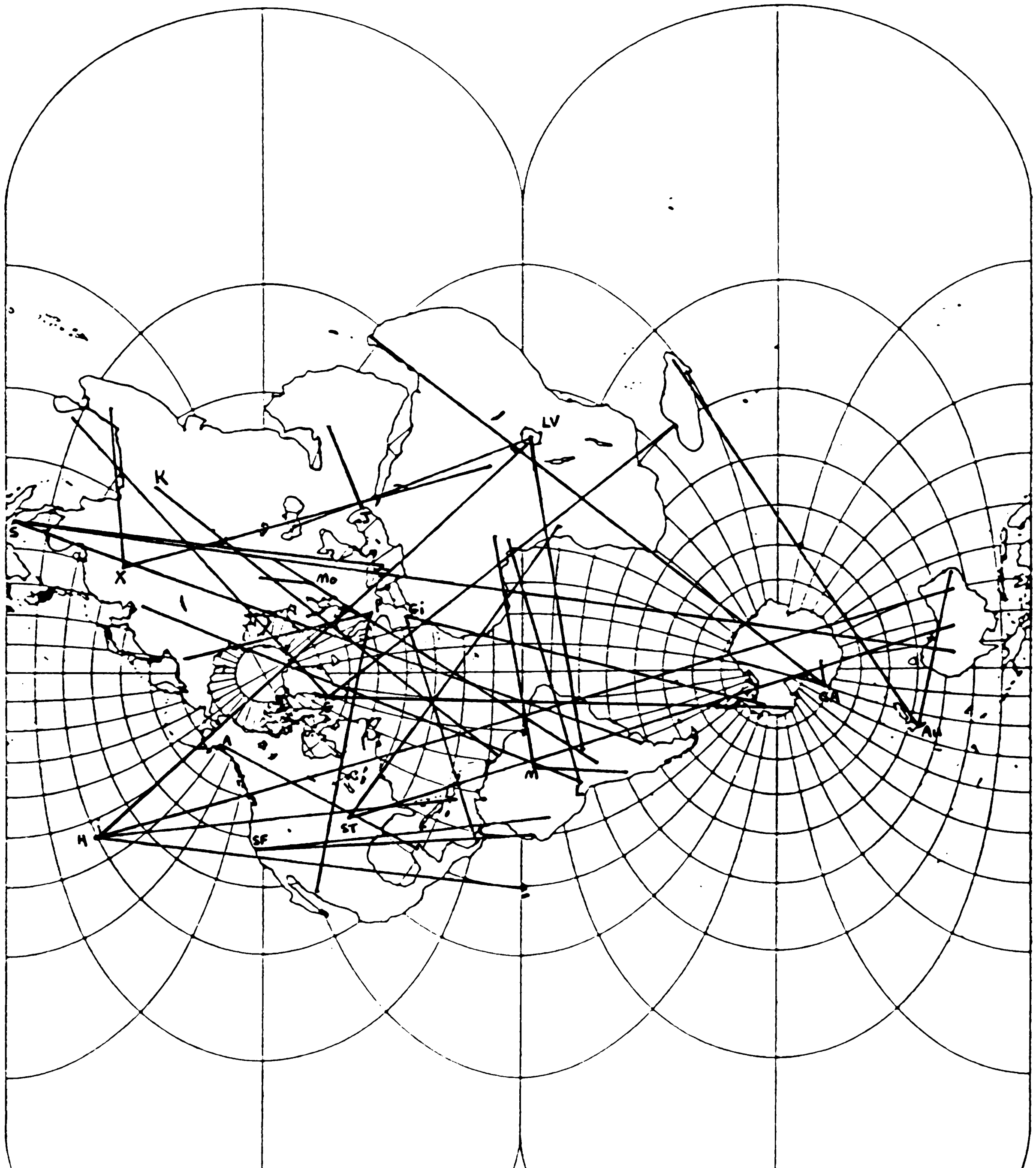

Figure H2: TRANSVERSE MERCATOR 4th grade

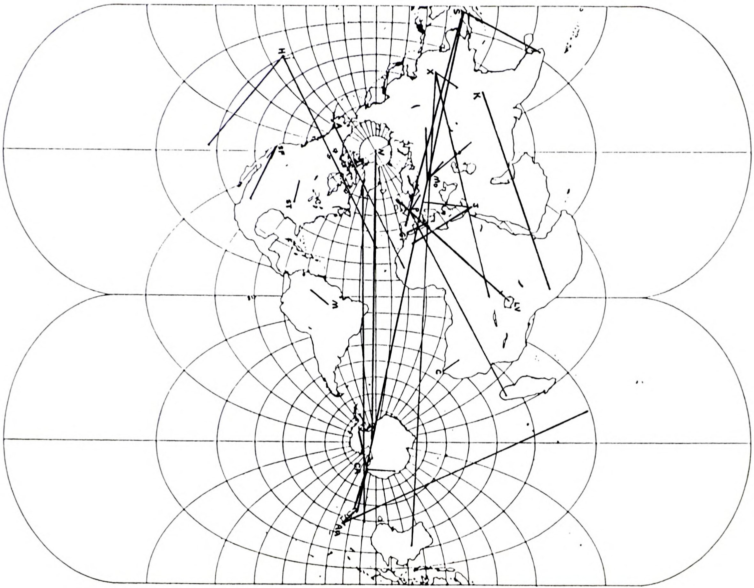

Figure H3: TRANSVERSE MERCATOR 6th grade

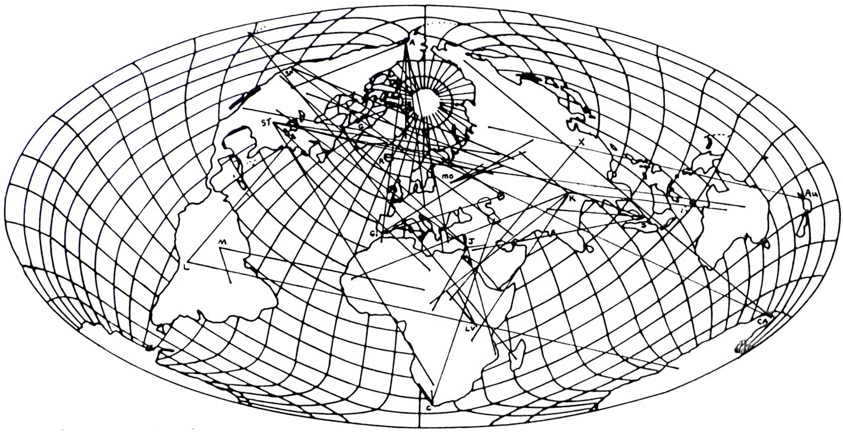

Figure I1: OBLIQUE OVAL (BARTHOLOMEW) 2nd grade

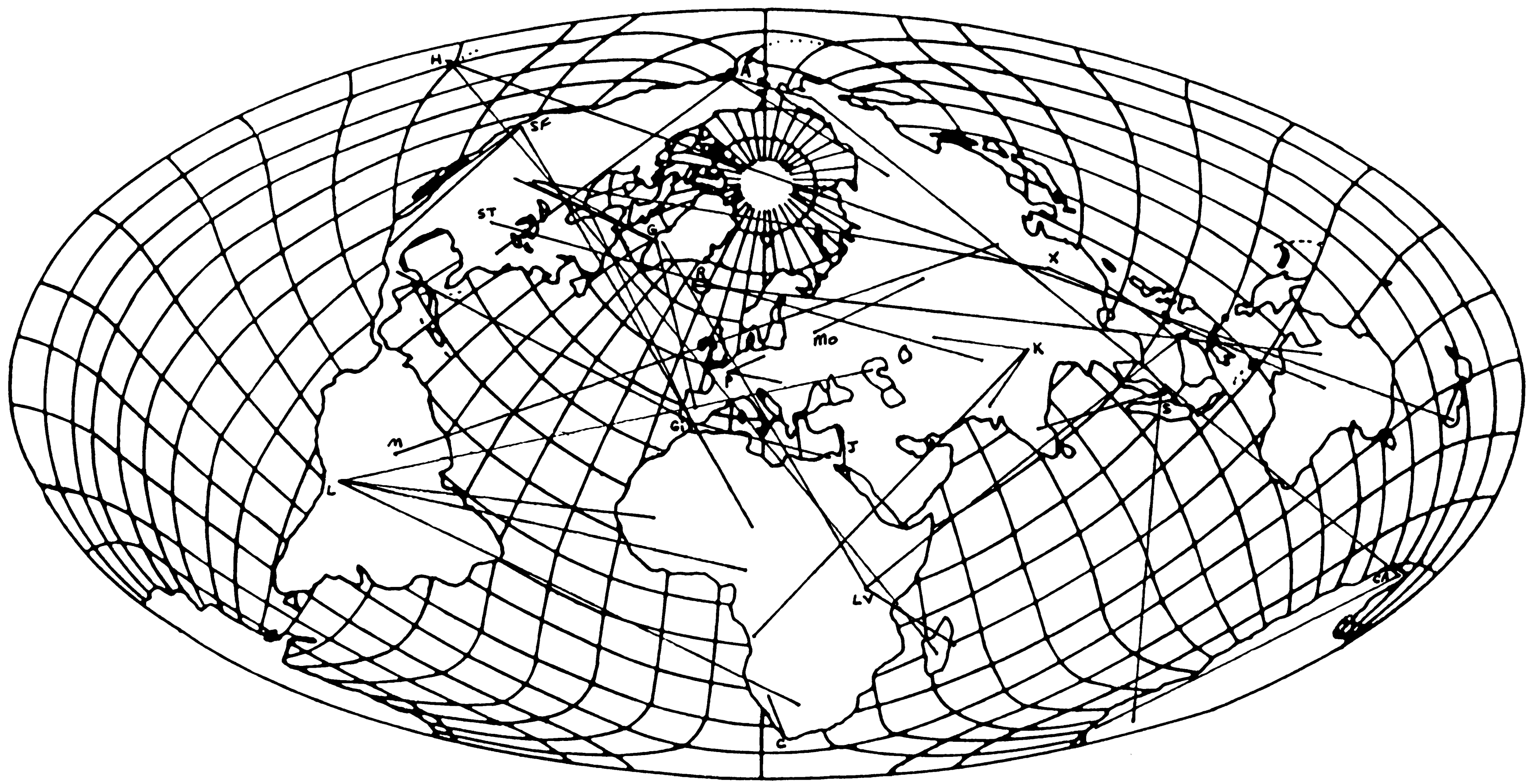

Figure I2: OBLIQUE OVAL (BARTHOLOMEW) 4th grade

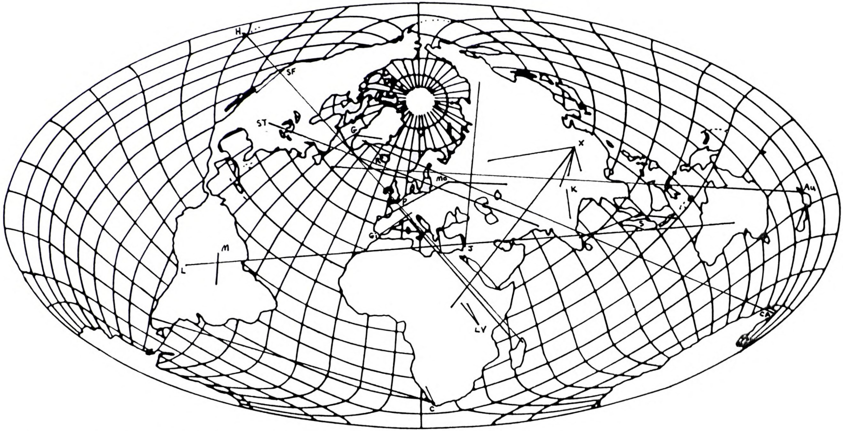

Figure I3: OBLIQUE OVAL (BARTHOLOMEW) 6th grade

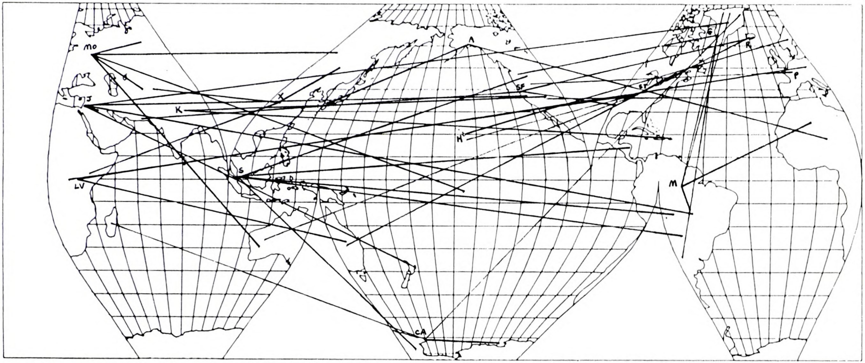

Figure J1: INTERRUPTED WITH CONTINENTAL SPLIT (SINUSOIDAL) 2nd grade

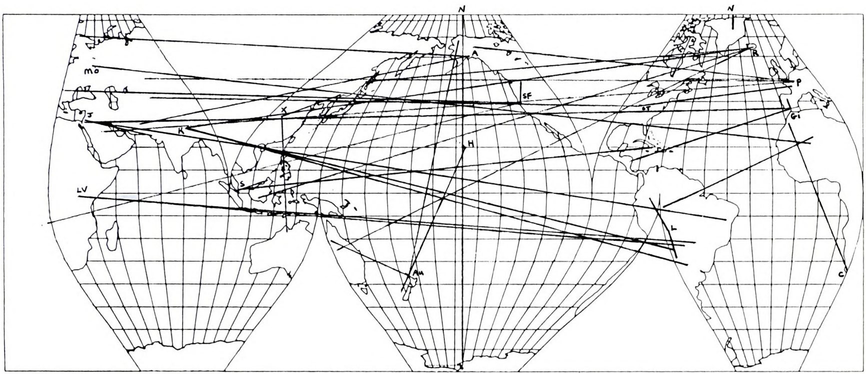

Figure J2: INTERRUPTED WITH CONTINENTAL SPLIT (SINUSOIDAL) 4th grade

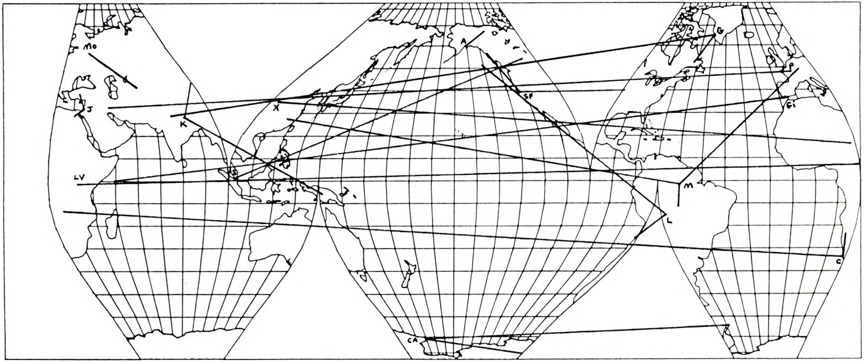

Figure J3: INTERRUPTED WITH CONTINENTAL SPLIT (SINUSOIDAL) 6th grade