A Functional Taxonomy For Mapping In Geographic Education

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A taxonomy of map use functions, and the map types associated with each, is proposed as a tool in developing more logical sequences of classroom activities that introduce students to maps, their various uses, and to the processes of geographic thinking. Awareness of the great variety of map types and functions is needed so that students can improve their skills in creating and using the appropriate map for inventory, navigation, measurement or analysis tasks. Traditionally we categorize maps on the basis of content, scale, or user group. But this fails to illuminate the different ways we design maps so as to address a variety of spatial problems. This paper discusses criteria that can be used to create such a taxonomy and applies them to a prototype taxonomy. It identifies four genera of map use tasks or questions and more than fifty species of specific models, drawings, and map types. A number of implications for geographic education are noted.

***Keywords:** taxonomy, mapping in geographic education, tasks in map use, geographic thinking.*

INTRODUCTION

When we talk about mapping in a child's world, what kinds of maps are we talking about? What kinds of maps do they need in school? At play? Adults classify maps in many traditional ways: by content (e.g., soils maps), by scale (e.g., atlas maps, city plans), or by user group (e.g., mariners or blind people). Some of these map names have generally agreed upon definitions. But the logic of these classifications and the meaning of these names may not be known to school children or their teachers (1). If we want children to use maps as tools for thinking, analysis and argument, they will need to know what map types best solve what problems and how to design them.

A taxonomy of map functions for geographic education can assist in this in a number of ways. First, the very nature of a taxonomy establishes the functional differences and similarities between the various classified members. For young mappers, the basic distinctions in a taxonomy should pertain to the kinds of problems they may wish or need to solve. Second, a function-based taxonomy can suggest to curricula designers the kinds of visual and intellectual skills children need for solving different problems and how they relate to the skills children already possess. This should provide some guidance as to what problems are easier to address and thus what questions should be the object of children's first mapping activities. From this, designers may then be able to develop more logical sequences for introducing maps and mapping (2) in the school curriculum and for streamlining our educational agenda. Of course, a number of researchers in such fields as psychology and education are also inquiring into the perceptual and motor skills of children and their pace of development (3). At some point, the results of that research should be used to modify sequences that we develop. But until that time, we should have first considered the variety of map products from an intellectual point of view and established the basic functional relationships among them. Creating a taxonomy is one way of accomplishing these goals.

Finally, and in a more general way, a taxonomy can clarify what questions geographers ask that set them apart from other scientists who ask questions about the world, i.e., the questions that are fundamental to geographic thinking. This paper discusses some criteria that can be used to create such a map taxonomy and applies them to a prototype taxonomy.

ON CLASSIFICATION

In studying any phenomenon, scientists want to be able to group individual representatives in some meaningful ways. This is done so that the relationships between these individuals are clearly defined and understood. Taxonomy is the science of classification. The most complex classifications are in the plant and animal worlds where scientists must contend with some 1,500,000 species. Perhaps the best-known taxonomic classification is the one by the 18th Century Swedish naturalist Carolus Linnaeus. It is a hierarchical system in which individuals are grouped on the basis of similar observable characteristics into seven nested categories or taxa: kingdom, phylum, class, order, family, genus and species (McKnight, 1984,194-5). Most familiar to us are the species, the basic unit of the classification, followed by the genus, the next level of organization. Each genus includes a number of species.

Taxonomists ask such basic questions as, for example, "What constitutes spiderishness?" It usually involves a critter having eight legs, silk-spinning organs, and whether they spin orb, funnel, rectangular or cobweb type webs (Hubbell, 1996). By asking these kinds of questions, primitive traits emerge that define levels or taxa within the hiearchy. The higher the taxon, the broader and more inclusive are the groups. The lower the taxon, the more closely related are its members and the more characteristics they have in common. In this way, a conceptual framework is created for clarifying the relationships among all individuals and groups of organisms.

It should be clear, however, that the purpose of any classification involves organizing our knowledge about some group of things with a specific purpose in mind. Thus there can be as many classifications as there are purposes. In considering maps or map use tasks, we clearly do not have the numerical problem of the natural scientists but we do make the kinds of groupings that might be found in a formal taxonomy. For example, we distinguish between maps that are large and small scale, thematic and reference, choroplethic and isometric, etc. Even though these categories are not mutually exclusive or comprehensive, they work relatively well as generalizations among knowledgeable mapmakers. Perhaps this is why there have been few formal attempts at producing a comprehensive taxonomy of maps. But in education, the terminology describing map types is often vague and not universally understood and their distinctions are more likely made on the basis of form or scale, and not of purpose.

For example, the curriculum for North Carolina (Teacher Handbook, 1992) makes reference to maps of the classroom and of the child's room at home, to county maps, state maps, and globes. While these maps are of quite different scales, they will likely be used by children to search for and locate specific features in them. Thus they share the common functional use of being used to record all objects in an area. The inventory or reference function is an important use of maps, but not the only one. More critically, decisions about content, generalization, and design for inventory maps are not the same as those decisions made for other kinds of maps. Unless children are given opportunities to produce a variety of maps as tools, not just inventory or reference maps, they may get a one-sided view of what maps might look like and what they can do (4).

As a result, children may fail to recognize the intellectual and functional distinctions between various kinds of maps. For children to solve problems with maps, they must know how each type of map differs structurally so that in creating their own maps appropriate steps can be taken in the selection of content, its generalization and symbolization. To assist in this, a taxonomy of map functions should describe the kinds of problems we can solve with maps and what types of maps are appropriate to each. In creating such a taxonomy, we may also discover the intellectual (and technical) difficulty of producing and using associated map types. This knowledge could then be used to develop a sequencing approach not only for introducing maps and mapping, but also to the geographical problems they may best address.

In examining curriculum materials, elementary textbooks, and atlases I have never seen such a taxonomy (5). Rather than attempt to deduce a taxonomic relationship between the rather narrow range of maps named in the curriculum, this paper considers some ideas that might be useful in creating a taxonomy based on map function.

QUESTIONS OF INVENTORY AND WAY FINDING

The essential and simplest intellectual question in mapping asks "What is there?" This provokes an inventory of the area in question and the recording with symbols and labels all features that the map scale allows. As a result, a map of a classroom and the globe can have a common inventory function but the details will be different: e.g., desks, wastebaskets, and bookcases in the former; oceans, continents and major cities in the latter. But we may wish to carry out a basic inventory at many scales; the map scale, however, will usually determine what things are noted. In a sense, this *scale-dependent generalization* allows us to manage the graphic complexity that comes with trying to show all objects at smaller and smaller scales. Thus a city plan, a topographic map at scale 1:250,000 and a continental reference map in an atlas can all be considered inventory maps but at various scales. We do not, however, normally make this connection and group them in this way.

A second basic question addressed by maps involves navigation and way finding. For this we select features that are appropriate to the mode and speed of our movement and that provide the necessary landmarks for that method of locomotion. For example, orienteering maps have quite different designs and exist at quite different scales from aeronautical and hydrographic charts. We might not think to include globes and city plans in this list, but they too include features appropriate to way finding by different means of travel. The former will include parallels and meridians (and thus reference to cardinal directions) whereas the latter makes use of specific buildings, boulevards, and nodes (such as important intersections or subway stations) as landmarks.

For both these questions, it is clear that scale defines "*species*" within the functional "*genus*" of "inventory" but "sub-species" within the functional "genus" of "way finding" or navigation. What other "*genera*" might we find useful? The measurement of angles, distances, and areas is a need traditionally met with sufficiently large-scale maps or those with special characteristics, e.g., conformality or equivalence. There are also various tasks of analysis for which we need to be particularly selective about map content and careful in the ways we classify, generalize, and display that information. Thus we can consider two other "genera" as the needs of measurement and of analysis. From the evidence of school texts and children's atlases, we seem to regard the first of these needs as the more important. But given the necessity of understanding abstract concepts about scale, distortion, and map projections, the skills of measurement are far less accessible to children than those of information selection and generalization, unless we restrict ourselves to very large scale maps. I would argue that the needs for analysis skills are just as valuable, and much more accessible. Perhaps they should even be given preference in our curricula.

QUESTIONS OF ANALYSIS

Inventory maps of small areas are perhaps the simplest maps we can have children produce. Everything in an area, such as their classroom, is included because it is there — no questions asked. Such maps allow us to address the simplest of "Where is...?" questions. But to answer the more difficult "Why...?" questions, we must be selective in what is shown just as we are selective with words when verbalizing a problem. To be selective, children must recognize the role that particular pieces of information play and learn to ask, in their map making, "Why do I need this?" and "How will it be used to illuminate my problem?" Denis Wood (1993, 51-2) would probably pose the additional question of: "What change do I wish to bring about in another's mind?" The consideration of such mapping questions, what I call *function-dependent generalization* (Castner,1983), is the more important concept than scale-dependent generalization for all questions of information manipulation and emphasis in graphic design revolve around it.

To understand *function-dependent generalization*, envision a continuum of maps that begins with those depicting individual things or *objects*. For example, in a neighborhood inventory map we may wish to differentiate the individuality of each house, e.g., "my house" from "your house." To do this, we need a separate symbol or label for *every* house. But to show why a school might be located in a particular place we need only to see the distribution of each house with school age children. To represent them, we need but one uniform symbol for we are now representing my house and your house as members of a class of things called "houses with school age children." For adults, this may not be a difficult distinction. But I wonder if it isn't too subtle an intellectual leap for children without some preparation? If they do not understand this distinction, then their ability to isolate a problem or illuminate a situation, i.e., to state a spatial proposition, will be limited.

But the problems of scale-dependent generalization, i.e., of dealing with graphic complexity, are relatively straightforward compared to those of function-dependent generalization, i.e., of intellectual complexity. This is because in the latter we need to eliminate, classify, or aggregate information appropriate to the questions to be addressed or the problems to be solved. This operation is at the heart of purposeful map use.

A continuum of maps which begins with one of individual things or objects can extend into many different directions. One important direction is in making spatial generalizations, what we call regions. The map of school districts, that was suggested above, is an example of a one-criterion region. It is perhaps the simplest kind of region that children should make. As they progress, more and more criteria can be used to make regions more reflective of reality. Land use maps are among the most complex where the distribution of many selected factors leads us to declare that some areas are significantly different from others. We may describe them with such general and ill-defined terms as residential, commercial, or industrial. But whatever the label, these are among the most useful products of map analysis.

QUESTIONS OF MEASUREMENT

Envision a continuum of mappable spaces that range from those that are too small to get into or are small enough to hold, to rooms, buildings, neighborhoods, communities, counties, states, countries, continents, and to the earth in its entirety. Each entity suggests successively a scale and thus an area of increasing coverage from what we call personal to large to medium to small (scale). But the calculation and use of a mathematical statement of the scale relationship of a map to the world involves arithmetic and measurement skills that the very youngest students may not have. Thus the introduction of the simplest measurement tasks should follow the lead of the mathematical readiness of the students. For example, with the acquisition of multiplication skills, children can begin to measure distances on maps and convert them to miles on the earth using simple verbal statements of the scale, e.g., one inch on the map represents one mile on the earth. But these activities are complicated by two other problems.

First, our ability to make precise measurements from maps as we move along this continuum of mappable spaces is influenced successively by the effect of the spherosity of the earth. The changes induced in the geometry of our maps affects directly the nature and amount of distortion in the structure of the space depicted. At the largest map scales the distortion is negligible. At smaller scales, as long as we don't attempt to measure distances, areas, or angles and directions, these changes in geometry present few problems in map use. But if we want to make measurements as map scale decreases, we must increasingly be aware of the nature and pattern of distortion in a given map projection and make use of its standard lines in order to keep errors of distance measurement at a minimum. But these ideas are complex, abstract, and often difficult to get across in school. Our pedagogic effort should lie in making it clear to children that distances, areas, and angles *can* be measured on very large scale maps or on the globe — two places where geometric distortion is not a problem. But, at the same time, they must be warned, if not allowed to discover, that extending these activities to medium and small scale maps may result in significant and unfortunate errors. They must come to understand what conditions must be met before such measurements can be taken. But this understanding of map projections and scale variation should not be a first hurdle to using maps (6).

Second, as we move from large to small-scale maps, we also are influenced by the reduction in space in which to display our symbols. We must therefore become more selective in what we map and more involved with the generalization of that information selected. This is a process we can call *"scale-dependent" generalization.* These problems suggest the educational strategy of starting children working with large-scale maps and progressing toward smaller ones so that any problems of geometric distortion and scale-dependent generalization are postponed.

On the other hand, as long as we don't attempt to make distance measurements, a certain level of structural control can be provided at all scales by the rivers or political boundaries in outline maps. With them children can analyze other questions, such as those relating to topological relationships, or examine patterns within and among various categories of information mapped by the enumeration areas shown, e.g., states (7). These are analytical activities, which can be accomplished before measurements even though they will involve problems of selection, classification, and aggregation. These will be considered momentarily.

Besides distance, we are also concerned with the measurement of area and angles. As with distance, we must first obtain a map of an appropriate large-scale or projection. It is critical to have knowledge of the tributes of the geographic graticules, which suggest conformality or equivalence. These can be used to deduce these attributes from small-scale maps and thus in deciding whether one can measure angles or areas on a map. Once an appropriate projection and scale is chosen, there are various techniques that can be used for measuring areas (8). There are also techniques and instruments for measuring angles and directions on appropriate map projections (9). This need will also show up as a part of way finding and analysis.

Finally, there are also needs for measuring elevations. For this, there are special skills and concepts such as the reading of profiles, form lines, contours, and inclined contours. Of these, we seem to pay special attention to contours but rarely to the intellectual steps, which lead to their understanding and applications elsewhere, e.g., in statistical mapping with various isolines. Photo and line anaglyphs would seem to be unfortunately neglected tools in this process. Since we also measure "elevation" when describing the surface of volumes, both real and imagined, this need may also be an aspect of way finding and analysis and someday may suggest a way of linking these map use tasks in school activities.

CONSTRUCTING A TAXONOMY

The above discussion suggests a rationale for four *genera* of map use tasks or functions for the *family* of graphics that we call maps. Clearly, there are other *families* of graphic displays on which some of these questions might be addressed. It is important, I believe, that we clarify for students the place of maps within and the distinctions between other kinds of graphic images such as abstract and pictorial art, advertising, photographs, and engineering and architectural plans. These other members can be differentiated by aesthetic criteria, requirements for accuracy, or simply on how well they replicate or resemble reality. But the four questions of map use suggested above seem the best criteria for the *family* of maps for education. Figure 1 describes 1) four *genera* of tasks in map use (in ALL CAPITALS), 2) specific map types (in all lower case letters) that best serve them, and 3) defining activities (in Caps and Lower Case Letters) which differentiate *subdivisions* within certain areas of the taxonomy. As will become evident, we do not have a full array of names in our map lexicon so that some awkward or verbose ones have been created in order to fill out the taxonomy. We may eventually come to some consensus over shorter, more succinct forms for them.

Maps for Inventory and Way Finding

The simplest map intellectually, and the most flexible in handling all map use tasks, is the one in which there are only individual, labeled and relatively unclassified things within some small familiar area, as with the map of a classroom, Figure 2. If its coverage is restricted to small areas of the earth's surface, students can make measurements from it, navigate within it, and ask analytical questions of it although not in the most efficient or effective way. For these non-inventory activities, more specialized map types are required.

For the *genus* of inventory tasks, the scale of the map to the things we might inventory and label we are restiricted by. Thus *species* of maps within this *genus* are scale determined. And we have quite well known and accepted names for most of these maps; the same will not be true for some of the other tasks. A selection of these are listed in sequence, from small scale to large scale, in Figure 1.

For the *genus* of navigation tasks, the *species* of useful maps must reflect the mode of travel. For each, landmarks and aids to navigation are determined by the means of (or restrictions to) locomotion and the speed of that movement. Navigation by foot occurs in many different places. Thus public area maps include such things as mall maps, theatre and stadium seating charts, and parking lot diagrams. Within each of these *species*, there will be a number of *sub-species* that are differentiated by map scale.

Maps for Analysis

Unfortunately, the tasks involved in analysis are not nearly so clear or easily defined. The problem can be seen in Figure 2. There, the desks share uniform shaped symbols but their uniqueness is determined by their label: e.g., Jill, Paul, etc. But if we want to consider a specific distribution, for example of brown-eyed children, we must change our map design in fundamental ways (Figure 3): we eliminate unnecessary information (e.g., the flag, the waste baskets, and all the labels); the desks become simple squares referring to indi-

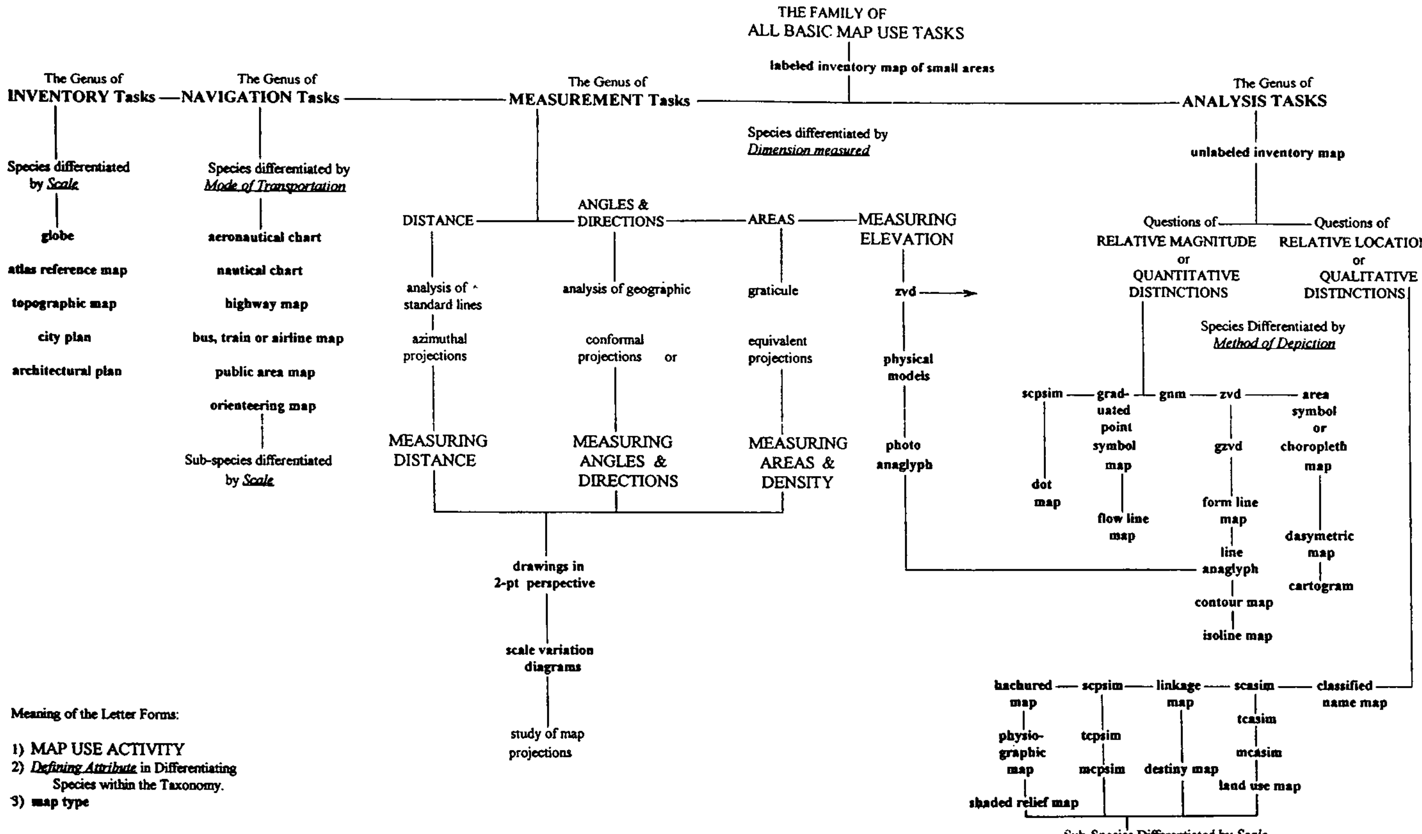

Figure 1. A taxonomy of map use tasks.

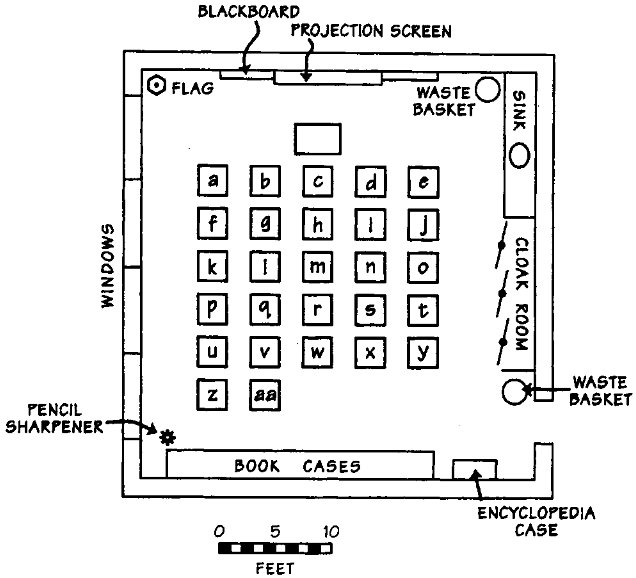

Figure 2. A labeled inventory map. A fifth grade classroom after one from *Thinking About Ontario*, p.11. Each letter stand for the name of a student sitting at that desk.

viduals who sit there; and attribute information (the color of the child's eyes) is used to indicate (by shading the corresponding desk symbol) which students fit into this category.

In doing this, we transform the *labeled inventory map* of Figure 2 into an *unlabeled inventory map*, Figure32. It is representative of all maps of this *genus* of analysis. But to be of practical use, we must define its *species* in more specific terms. The basic division involves questions of relative location and qualitative distinctions and questions of relative magnitude and quantitative distinctions. Let us examine each of these.

In Figure 3, we have mapped all occurrences of a single phenomenon (in this case, brown-eyed children) using one common point symbol, a square, for each. We can ask a number of questions of this latter image as it relates to total number, place occurrence, or relative location of this single phenomenon. But there is a subtle divide here for if we want to examine the density of the symbols, we are suddenly considering a question of relative number or magnitude from place to place. In other words, we must recognize two classes of

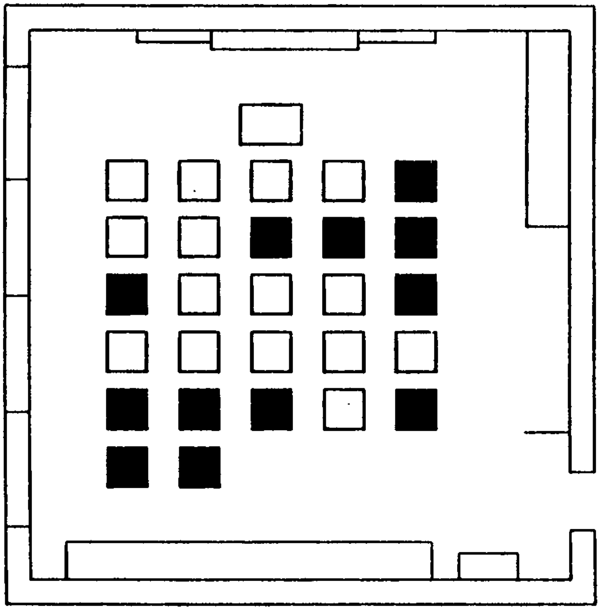

Figure 3. An unlabeled inventory map using dark point sysmbols to indicate which students have brown eyes. After a map from *Thinking About Ontario*, p. 12.

analytical questions: those which consider qualitative questions in things and those which address quantitative ones. In both cases, the *species* are best differentiated by the kinds of information examined and the symbols used to display it, i.e., the method of depiction.

1. Maps for Examining Relative Location or Qualitative Distinctions

A map using POINT SYMBOLS to represent occurrences of a single category of *point or discrete phenomena* might be called an "unlabeled point symbol inventory map," or "upsim" as in Figure 3. Since it displays the distribution of individuals with particular qualities, it is more specifically a *single category point symbol inventory map* (or for convenience here, *scpsim*). We might be tempted to call it simply a *dot map* but this name has strong connotations with the quantitative mapping of information collected within enumeration areas. There, each point symbol represents more than one unit of the phenomenon.

Figure 4. A linkage map showing the origins of materials and workers that were brought to Edmonton, Alberta to design and publish a children's atlas.

More complex distributions can be analyzed when two or more categories are shown in a *two-category* (*tcpsim*) or *multiple-category point symbol inventory map* (*mcpsim*). For example, each desk square in Figure 3 could be colored to match the color of the child's eyes (i.e., blue, brown, dark brown, or green), we would have a four category example. Another example of using multiple categories is the tourist map that uses various pictographic symbols to represent different services of interest to travelers, e.g., hotels, golf courses, and scenic views (10).

We can also ask questions about the relative location or qualitative distinctions among *linear features* by simply mapping them with LINE SYMBOLS. But the primary question we are asking involves where the lines are going, i.e., what are the origins and destinations of these routes. In mapping these, *linkage maps* describe topological relationships or connectivity. A small-scale example, Figure 4, shows the origins of materials and workers which came together in Edmonton, Alberta for the design and publication of a children's atlas.

We can also study questions of connectivity, either when it is potential (as with a road system in which we are only effectively linked when we make the drive in one direction or the other) or actual (as with scheduled bus, train, or airline service, as in Figure 5 (11).

A *destiny map* is a *linkage map* which shows the movements of materials or people when there are stops at intermediate locations between origins and destinations. In other words, it is a *linkage map* with intermediate stops. They are particularly interesting when applied in genealogical studies where, for example, we connect on a map the birthplaces of a child's grandparents and parents with the child's birth town.

We can also ask questions about the nature of *defined AREAS* such as states or countries. In the simplest case we could use a *single-category area symbol inventory map* (*scasim*) to show some quality or attribute that is common to certain areas. During Presidential elections, we might see maps showing, for example, states won by one of the candidates. More often we would see *two-category area symbol inventory maps* (*tcasim*) which show states that were won by Republicans and those that were won by Democrats. When more than two categories are shown, we would have a *multiple-category area symbol inventory map* (*mcasim*) as in Figure 6. While a form of inventory mapping, the purpose is to describe classroom *areas* characterized by the languages one might hear spoken within them — an attribute that extends beyond the desk itself, and connotes the language the child speaks at home. A smaller scale example might show the types of business practiced in each shop in a mall or the type of government or economy in various countries. Making any of these maps for different times allows for comparisons and the detection of trends. The most sophisticated maps of this *genus* are the *species* of *land use maps*. In all cases, *sub-species* would be determined by variations in map scale or coverage.

The NAMES found in different places can also be selectively mapped for analysis. A *classified name maps* can address many questions about culture, natural history, and economic activity (See Gritzner, 1987-88). In another case, Jouris (1994) shows how names that have some particular theme may, when mapped, reveal interesting patterns across the United States. Two examples are mineral

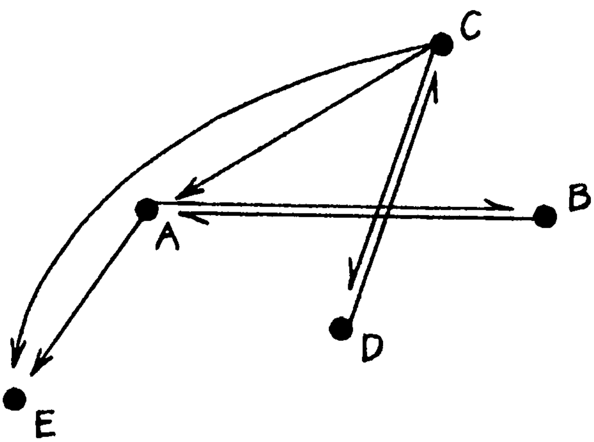

Figure 5. A linkage map showing the available airline service between five Northeastern cities, symbolized by the first letter of their names. It is clear that there is not return air service between some paris of cities. From Castner 1995, 148.

resources from places like Tin City, NC and references to the Bible, as with Bethlehem, PA. Dick (1996) examines the occurrence of women's names in the Kentucky landscape.

I have also listed three kinds of maps that can answer questions about the form of the land; hachured maps, physiographic diagrams, and shaded relief maps. They do this in visual, not mathematical, terms so that they answer qualitative questions of relative elevation and surface complexity.

2. Maps for Relative Magnitude or Quantitative Distinctions

As with questions of relative position and qualitative differences, there are five *species* of maps related to the types of symbols used. The simplest quantitative, unlabeled inventory map would be one using a SINGLE POINT symbol to represent each occurrence of a phenomenon. Such maps are, in fact, quite rare. They show, by changes in dot density, quantitative variations across the map. They are the same in form as the previously described *scpsim*, only the

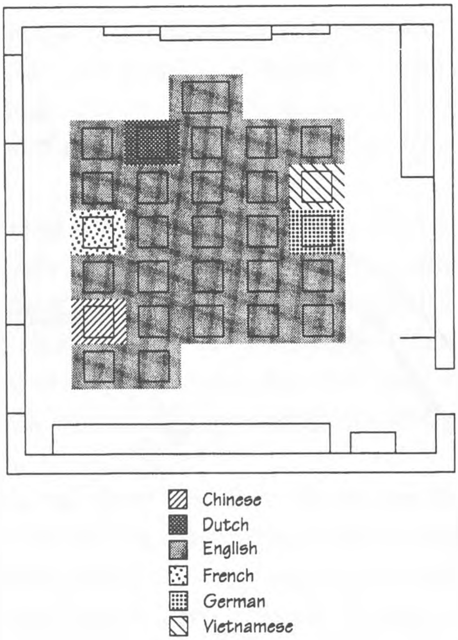

Figure 6. A mcasim map. Areas in a classroom where languages spoken in the student's home might be heard. After a map in *Thinking About Ontario*, p. 12.

question addressed is different. A logical educational sequence would have children make simple, one phenomenon dot maps (*scpsim*) (12) as a first step in learning about data classification and analysis. Once they have faced the inevitable problems of dot size and symbol crowding in cluttered areas, they can explore other solutions.

One is where many point symbols are used, each representing some constant value, e.g., 50 bushels of corn or 100 cows. These are true *dot maps* that are commonly found in textbooks and atlases and are based usually on data derived from *counting* the total number of *discrete objects* within an enumeration areas.

Another solution, when children run out of space to put legibly all their dots no matter what their value, is to make *graduated point symbol maps* where the *size* (usually the *area*) of the symbols is made proportional to the magnitude of the phenomenon being represented: the greater the value, the larger the symbol. The logic behind the construction of various sizes area symbols should be explained by some obvious construction process (13). An alternative is to use a *graduated number map* where the actual number applying to the point or area is enlarged so that the number's height is proportional to its value. Viewers of these maps are able to respond to two graphic clues — the size of the symbol and the number value itself. While actually rare, such maps may be a valuable first step, before graduated point symbol maps, in illustrating the graphic principle (14).

We often wish to analyze phenomena that are quite different because they are distributed *continuously* across an area. To analyze them we must first *measure* them at various places. An example of such a phenomenon, water depth, can be seen in the soundings on a nautical chart. We might call such a display a *z-value display* (zvd) for it represents changes in the elevation or depth (the z-dimension) of the phenomenon that we consider to vary continuously from place to place, like soil fertility or atmospheric temperature. In these cases we are mapping the surface of geographic volumes. The "surface" values of the phenomenon are measured from some datum plane.

By graphically selecting a range or some extreme values in such a display, we can call attention to map areas where the values are critical to some activity. In the case of depth soundings, we might wish to emphasize waters of insufficient depth for a particular vessel or class of ships. There are few examples of such *graduated z-value* displays but they have educational value in providing an opportunity for students to solve a variety of problems by creating some alternate designs (see Castner, 1995, 174-5).

But most often, we wish to use such data to represent the continuous surface from which such data was derived, usually because we cannot see such surfaces -- they may be under water or simply an intellectual abstraction. For this we have developed several representative techniques. The simplest technically involves enclosing or isolating with a continuous LINE — a *form line* — soundings of particular values, as in Figure 7. They might relate, for example, to the draft of a particular vessel. Such a *form line map*, while not as accurate or sophisticated as a contour map, easily isolates areas of specific values or shows a general trend of slopes, not only for a mariner but also for a school child and at a fraction of the intellectual cost. Ultimately, we will want young mappers to study and master *contour maps* and various *isoline maps* (15). But perhaps they should first have more opportunities to study the map tools noted above. Two other tools would probably be useful in this introduction: three-dimensional *physical models* (Brian, 1994); and *photo* and *line anaglyphs* (16). These latter demonstrate dramatically how contours are supposed to be seen and what they show.

Flow line maps also use lines of various widths to depict the volume of movement between connected points. These symbols are made proportional in width to the data they depict. Understanding them would seem to be an extension of the idea of both linkage maps and graduated point symbol maps.

Finally, we can make use of AREA SYMBOLS to depict a number or range of values found within individual enumeration or counting areas. The darker the area symbol, the greater the magnitude of the variable. Because coloring in areas is so easy to do, we rarely consider the erroneous or misleading impressions such maps can give to users. For this reason, we should develop a logical sequence of *area symbol quantitative maps* (*asqm*) to illustrate the various problems that arise from 1) the unequal sizes and different shapes of the enumeration areas, 2) the uneven distribution of the data within them, and 3) the choice of the number of data classes and their numerical boundaries. Only with the understanding of these problems can children begin to use true *choropleth maps* and eventually *dasymetric maps*. Gersmehl's "pixel-coded maps" (1991, 132) are perhaps a good place to begin by mapping within simple grid-square overlays. By enlarging the size of squares in successive grids, we can begin to wrestle with the neglected problems of error and generalization.

Maps for Measuring Distance, Area, Angles, and Elevation (17)

For making these kinds of measurements, both *globes*, *topographic maps*, and any very large scale maps are useful because scale variations are either zero or relatively small for most non-engineering purposes. Each of these four different kinds of measurement tasks, however, suggests a different pedagogic procedure.

For measuring *distances* on any graphic image, we need to know where the scale is uniform and the same as that indicated by the scale of the drawing. In the simplest case, this means finding the *standard lines* — lines drawn at a consistent scale relative to the object. In the case of map projections, the earth's equator or two

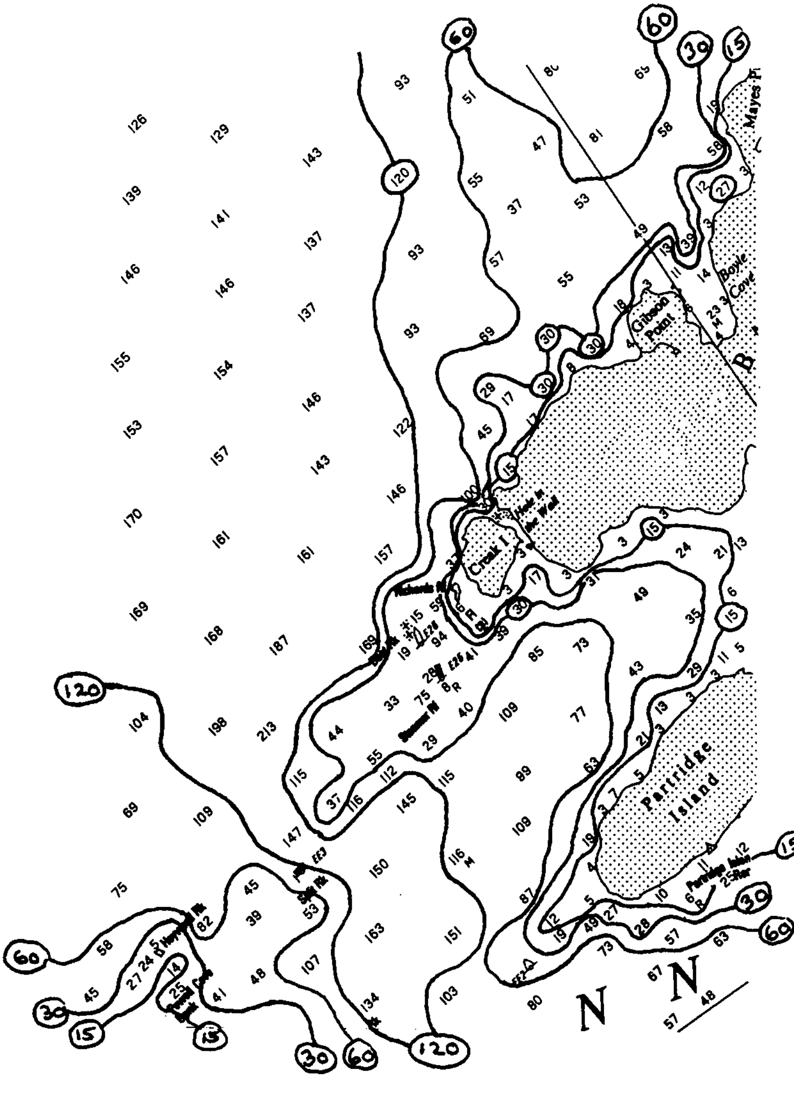

Figure 7. soundings of water depth and hand-drawn form lines isolating various depth zones. Modified from Castner 1995, 175.

standard parallels and perhaps one or more meridians are most often standard lines. If we know the pattern of these standard lines, then measuring distances near them or aligned to them can be reasonably accurate; elsewhere we can make considerable errors. Most of the family of azimuthal projections provide for measuring distances along a larger number of standard lines.

For measuring areas and angles or directions, we need to known if the projection is *equivalent* or *conformal*, that is, do they preserve area relationships or angular relationships on the globe. For extensive areas, two simple tests give some insight into this question. Do the grid lines cross at right angles? Is Greenland the same size as Mexico? If the grid lines don't everywhere cross at right angles, then it can't be a conformal projection. If Greenland is larger than Mexico then it isn't an equivalent projection. An examination of the Mercator (conformal) and Gall-Peters' (equivalent) projections will show how preserving one trait (shape or area) often severely distorts the other. There are, of course, a number of projections for world maps that attempt to find some compromise between these extremes, e.g., Robinson's.

Having considered these questions, it should become clear that scale is a variable and ever changing quality of any given map. Students can discover this by making *drawings in two-point perspective*. In interior locations, constant sized vertical lines in walls (corners, door jams, etc.) are all drawn at different lengths relative to the one closest to the viewer, the "standard line" (18). The study of such drawings lays the groundwork for understanding the various *scale variation diagrams* (see, for example, Robinson et al., 1995, 77f) which show us the "best," i.e., least distorted areas of any map projection, no matter what its *aspect*, i.e., on what point or graticule line is it centered. Finally, students may then be ready to study in meaningful ways the various *map projections* available. But even if this study comes at the end of a sequence of activities, those activities will have given students useful experiences in the concepts involved in making various kinds of measurements from maps and to learn about some of the limitations in making them.

The *description* of elevation change on maps begins with ordinal distinctions. *Physical models*, *anaglyphs*, and the series of relief depicting maps mentioned above are among the simplest tools for this. But for interval and ratio *measurements,* we will need elevation information at points above some absolute or relative *datum plane*. Thus a logical sequence of instruction starts with an array of z-values (zvd) and continues down the column described in the taxonomy. One wonders, however, whether children really need ratio or even interval elevation information to solve their problems? I suspect *contour maps* can be introduced much later in the curriculum than has been our practice, and that these other simpler forms should take precedence in our talk about elevation and relief.

CONCLUSIONS AND IMPLICATIONS

This preliminary or prototype taxonomy, Figure 1, names over fifty *species* of models, maps or drawings which perform four *genera* of map use tasks (19). Collectively they describe sequences of questions which students can ask of geographic or spatial information using these associated products. If children are to become facile in using maps and graphic images for thinking, analysis, and argument, then they must be given experience and expertise in all of these areas. Since few schools may be willing or able to teach all of these areas systematically, it may be necessary to consider the relative importance we place on the various map functions. In addition, it may be useful to develop classroom activities that integrate some of these functions and sequences and so provide both hindsight (what lessons ans concepts it build upon) and foresight (what lessons and concepts it anticipates). With this, elementary and middle school teachers can better come to know and understand how the particular step(s) fit together and why they may wish to engage in them. These decisions will ultimately be moderated by teachers with the knowledge of their students' skills and past experiences and the curriculum goals they wish to pursue. It is my contention that most of these steps and sequences are missing from our geographic and cartographic curricula and thus their logic and conceptual bases are also missing. We should guarantee that they are there.

The development of the taxonomy suggests that in planning purposeful mapping in schools we should consider:

1) continuing to first introduce mapping to children with inventory

tasks using very large scale maps, and so avoid problems of distortion brought on by the increasing influence of the earth's spherosity as scale decreases;
2) limiting at first the measurement tasks to very large scale maps; avoiding these at medium and small scales with the exception of using the globe itself;
3) introducing way finding and navigation tasks in very small environments, experienced by children on foot, where they can establish the meaning and use of local landmarks;
4) working with questions of relative location and qualitative distinctions among geographic information before considering those of relative magnitude and quantitative distinctions;
5) beginning with maps that have the necessary structural control built in or on which no angular or distance measurements will be made; and
6) beginning with maps with unclassified information or unaggregated data.

NOTES

(1) As a result, it is difficult to discuss the problem of map types because most any name mentioned will have meanings to individual readers that are not shared by all. The reader is asked to accept the terms used in the initial discussions with some flexibility until the taxonomy is developed. At that time, it will be appropriate for the community of cartographers and educators to consider better names for the longer, but sometimes rather clumsy, descriptive names and acronyms that are found in the taxonomy.

(2) In an earlier work, I tried to make the case for mapping as a more inclusive and useful term than simply map making to describe the cartographic contribution to geographic thinking. There (Castner,1990,11) I describe mapping as: THINKING about the world and some aspect of it or phenomenon in it; DETERMINING the essential characteristics of that aspect or phenomenon; ESTABLISHING a communication goal, i.e., the use(s) to which a representation will be put, or the problem to be solved; CONSIDERING the various forms and modes of representation that can speak to that goal; and only then EXECUTING some representation that best addresses that communication goal or problem solution.

(3) For a recent commentary on this research, see Downs and Liben, 1997, pp. 21-45.

(4) In fairness, the North Carolina curriculum also mentions "primary maps," route maps, wall maps, physical resource maps, reference maps and "shoe box dioramas." One wonders, however, if these maps are categorically different? Except for their scale or area of coverage, I suspect they are not. In other words, they may all be variations on the basic inventory map.

(5) Muehrcke and Muehrcke (1992) has created a three-part "taxonomy" based on the cognitive processes of reading, analysis, and interpretation: of extracting information from a map; of manipulating that information to create new information; and adding non-map information to establishing meaning and interpretation. These processes can be applied to all maps, regardless of how they were designed. Since there is no way to predict what other information might be brought to a map using encounter, the taxonomy developed in this paper is related only to reading and analysis and is based on map use function for this makes a critical impact upon any design.

(6) Since the special limitations on measurements can be overcome by the choice of one's map projection or of using only certain parts of a projection, a function-based taxonomy might not include any special types of maps for these purposes. On the other hand, it may suggest some logical sequences for introducing these ideas. In this case, knowledge about the existence and position of standard lines (i.e., those along which map scale is true and uniform) is the most useful information in determining where distances can be measured on a map.

(7) A secondary question asks "Do we want children to construct their own control?" At the simplest level, an alpha-numeric grid could be taped on the classroom floor to correspond to a grid on a convenient sized outline map. The "control" is provided by the grid squares and mapping involves transferring information, square by square, from the room to the map. The size of the grid also determines the accuracy of the map. A more complex approach would involve using a simple plane table and alidade outside the school building to establish the positions of prominent landmarks in relatively restricted areas, such as the school campus or a nearby park. Other information is triangulated in reference to these landmarks.

If you think about it, we can control both the degree of structural control and the degree of classification or aggregation by manipulating the area of coverage of our maps. But the critical issue seems to lie with the type of questions we wish to address with maps. If they involve the measurement of distance, area, or angles, then special care must be taken in assuring an appropriate degree of structural control, or in restricting our mapping to relatively small areas or to the globe. For all other questions, the need to be selective in what information is used and how it is generalized becomes paramount. In my view, this side of mapping has been almost completely ignored. We have, instead, favored describing map projections and how they are constructed without addressing the concepts which underlie their meaningful use. Thus a taxonomy of maps should reflect the basic divisions of map use.

(8) For example, various forms of the dot planimeter (which call for counting dots or grid intersections) are simpler to use than instruments such as a polar planimeter. But a third approach, using a chemical balance, may have more educational advantages than either of these. A map is cut up into its constituent areas. These pieces of paper are carefully weighed and then the weights are reduced to percentages of the total weight (area) of the map at its scale. For medium and small scales, the map must be on an equal area or equivalent projection.

(9) For measuring angles at medium and small scales, any of the conformal projections are required, e.g., the stereographic or the Mercator. Only the Mercator was constructed to allow the construction of lines of constant compass direction. But if we are also considering travel of great distances across continents or oceans, we would want to follow the shortest routes along great circles. Only some oblique version of the gnomonic projection will allow these travel routes to be plotted as straight lines.

(10) Unfortunately, such maps often use different shaped, equal sized point symbols but of only one color. This was probably done as a convenience to the map maker and not the map user. As Bertin (1983,156-8) illustrated some time ago, this practice makes it difficult for readers to discriminate and thus sort the various symbols. For purposes of visual analysis, perceptual research suggests that using symbols of different hues to represent different classes of tourist information would be easier to decipher (Williams, 1971).

There is also an unfortunate practice of using point symbols to represent area phenomena, e.g., a single, out-of-scale image of a cow to represent a region of dairy farming of unspecified extent. Given the confusing logic of representing the quality of an undefined area with a single point symbol (which stands for only one of many that might actually be seen in that region) suggests that we should not recognize this as a useful map type in a taxonomy.

(11) For linkage maps illustrating problems of connectivity, congestion, and individual behavior, see Castner, 1995, Chapter 6.

(12) Gersmehl (1991, 122) calls them "repetitive-symbol maps."

(13) See Castner et al (1981, 16) for an example.

(14) See Dickinson (1963, 90 and 96) for examples.

(15) The category of isoline map includes all the great variety of specialized maps that use isotherms, isochrones, isohyets, etc.

(16) Line anaglyphs are made of two sets of slightly offset contours, one in magenta and one in cyan, which are viewed through lenses of these two colors so that each eye sees only one set. The brain then creates a virtual image of the undulating surface. The photo anaglyph does the same thing but by using offset photographic

images.

(17) The task of measuring density can be accomplished in several different areas of the taxonomy. To measure it *in absolute terms*, one must map sites on an equivalent projection or one of large scale. Measuring it *in relative terms* means estimating physical clustering by eye with a scpsim or a dot map or with an area symbol map where densities have been calculated and viewers differentiate between the value of various area tone symbols.

(18) Drawings in two-point perspective are not maps but they provide a useful pedagogic tool in bridging the gap between how we see objects and surfaces around us and map projections. Such drawings do this by exhibiting many of the characteristics of map projections. For example, the noticeable and measurable linear distortion can be used to analyze scale distortion across the drawing just as we do with map projections.

(19) We can now go back and examine the map types found in the North Carolina Curriculum as listed at the beginning of the paper and in footnote #4. Of the eleven types of maps mentioned, eight are inventory in nature and are represented in the taxonomy by five maps. A ninth relates to navigation (presumably by road — the route map). A tenth answers a question about the relative location of physical resources (a mcpsim?), and the eleventh (the shoebox diorama) which might be related to physical models. Thus, over forty of the images in the taxonomy are not represented in that Curriculum.

REFERENCES

Bertin, Jacques. 1983. *Semiology of Graphics*. Trans. William J. Berg. Madison: U. of Wisconsin Press.

Brian, Sam. 1994. *Geography and Mapping from Terrain Models*. New York: Geography and Mapping Institute, Bank Street College of Education.

Castner, Henry W. 1983. Research in cartographic communication: any implications for introducing maps and mapping to young children? *The Operational Geographer*. 2: 13-16.

Castner, Henry W. 1990. *Seeking New Horizons: A Perceptual Approach to Geographic Education*. Montreal & Kingston: McGill-Queen's University Press.

Castner, Henry W. 1995. *Discerning New Horizons: A Perceptual Approach to Geographic Education*. Pathways in Geography Series Title #13. Indiana: National Council for Geographic

Education.
Castner et al. 1981. *Thinking About Ontario: A Hosford Study Atlas.* Toronto and Edmonton: Hosford Publishing.
Dick, Lalie (1996). From Hazel to Nancy, women are on the map. *All Around Kentucky.* Official Publication of the Kentucky Farm Bureau Federation, LX (#6, Nov), 10-11.
Dickinson, G.C. 1963. *Statistical Mapping and the Presentation of Statistics.* London: Camelot Press.
Downs, Roger M. and Lynn S. Liben. 1997. Geography and the Development of Spatial Understanding. In *The First Assessment: Research in Geographic Education*, eds., Richard G. Boehm and James F. Petersen, pp. 21-45. San Marcos: The Gilbert M. Grosvenor Center for Geographic Education.
Gersmehl, Philip J. 1991. *The Language of Maps.* Pathways in Geography Series #1. Indiana, PA: National Council for Geographic Education.
Gritzner, Charles. 1987-88. The geographic landscape of place names. *The Social Studies Teacher.* 9, no.9: 3,8.
Hubbell, Sue. 1996. How taxonomy helps us make sense out of the natural world. *Smithsonian*, May:140-151.
Jouris, David. 1994. *All Over the Map. An Extraordinary Atlas of the United States.* Berkeley: Ten Speed Press.
McKnight, Tom L. 1984. *Geography: A Landscape Appreciation.* Englewood Cliffs: Prentice-Hall.
Muehrcke, Phillip C. and Juliana O. Muehrcke. 1992. *Map Use*: 3d Edition. Madison: JP Publications.
Robinson, Arthur H. et al. 1995. *Elements of Cartography, 6th Edition.* New York: John Wiley.
Teacher Handbook. 1992. Raleigh: North Carolina Department of Public Instruction.
Williams, L.G. 1971. Obtaining information from displays with discrete elements. In Map Design and the Map User, *Cartographica*, II:29-34.
Wood, Denis. 1993. The fine line between mapping and mapmaking. *Cartographica.* 30, no.4:50-60.

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