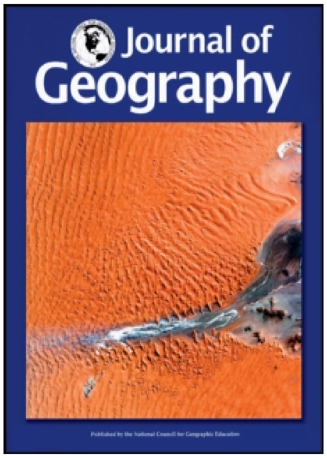

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Children's Choice of Visual Variables for Thematic Maps

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Abstract

The aim of this research is to examine how children use visual variables to represent nominal and ordinal data on thematic maps. Greek students from first (six- to seven-year old), second (seven to eight-year-old), and third grades (eight- to nine-year-old), without any systematic cartographic experience, were invited to participate in the composition of thematic maps at the stage of symbolization of various lists of items/attributes, using a specially designed software tool. The results revealed that many students, when making cartographic decisions, discovered basic principles of the application of visual variables in symbolization of nominal and ordinal data and expressed their preferences.

Key Words: *cartography and children, visual variables, thematic maps, display maps*

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Introduction

The term "visual variables," coined by Bertin (1967/1983), has been very influential in cartography, where it is used to define the perceived differences in map symbols that represent qualitative and quantitative characteristics of spatial phenomena (Robinson *et al*. 1995). Although studies have been carried out that examine the ability of children to identify and interpret map symbols (Gerber 1984; Downs, Liben, and Draggs 1988; Wiegand and Stiell 1996; Anderson 1996), the manner in which children attach meaning to symbols has not been sufficiently clarified. Anderson (1996) points out the need for further studies that focus on the role of visual variables in symbol identification by children.

The present study focuses on children as a special group of map users and on their ability to attach meaning to symbols based on visual variables. The aim is to examine how first to third grade elementary students (six to nine years of age) use the visual variables to represent nominal and ordinal data on thematic maps. The abilities of children as map users and more analytically their ability to interpret map symbols are discussed. A short reference on the way visual variables are used in cartographic practice is cited. Finally, the results of a test that has been conducted for the purposes of the study, with participants drawn from an elementary school in Athens, are mentioned and discussed.

Children as Map Users

The topic of map use by children has been approached mainly from two research traditions: from developmental studies and from cognitive studies (Gregg and Leinhardt 1994). Since the 1970s, Piaget's theory of cognitive development, and especially spatial thinking, has been immensely influential. Educators and cartographers turned to Piaget to define the abilities and limitations of children as map users (Robinson and Petchenik 1976; Downs, Liben, and Draggs 1988; Downs and Liben 1991) and to design appropriate maps and atlases for children's use (Randhawa 1987); to determine the ages at which children can be introduced to cartographic concepts and mapping skills; and to develop teaching methods and curricula for cartography (Muir and Frazee 1986; Castner 1990). Castner (1990) defines mapping as the ability to decode the representation of space on a map, to locate features on a map, to establish relationships between these features, and finally to comprehend map symbols. Up until the late 1980s, research and teaching practice focused almost exclusively on children over eight- to nine-years-old, a threshold age for the development of spatial thinking according to Piaget and Inhelder (1967).

In the last two decades, results mainly deriving from developmental studies support the view that the spatial abilities and map-thinking skills of very young children (three to four years of age) and preschoolers (five years of age) have been underestimated. Marzolf and DeLoache (1994) cited that three-year-old children can understand the basic relationship between a place and a representation and are able to use a very simple map to find a hidden object in a room. Sowden *et al.* (1996) discovered that four-year-old children have air-photo interpretation abilities; other researchers maintained that at the age of five children can extract spatial relationships from simple maps of a room (Presson 1982; Bluestein and Acredolo 1979), and are able to use a map for simple navigation tasks (Blades and Spencer 1986, 1987, 1990; Freundschuh 1990; Blades, Sowden, and Spencer 1995; Bremner and Andreasen 1998). Nevertheless, debates about the mapping abilities of children are still taking place among researchers. Blaut (1997, 168) argues that "children of school-entering age have sturdy mapping abilities and can readily cope with map-skills curriculum," whereas Liben and Downs (1997, 159) argue "for *early beginnings* but not *early mastery* of map understanding." Interpreting their research results based on Piagetian theory of spatial development, Downs, Liben, and Draggs (1988) and Liben and Downs (1993, 1997) maintain that even first and second graders experience difficulty in understanding symbolization and the geometric correspondence among space, person, and map. Today, the view prevails that by the age of school entrance children can be introduced to mapping activities, and even Liben and Downs (1997) support early education in geography and mapping. Over the last twenty years, a growing body of cartographic research studies has focused on preschoolers and children in early grades of elementary school as map users, and their abilities in map-reading and way-finding tasks (Ottosson 1987; Trifonoff 1995; Anderson 1995, 1996).

Developmental studies focus on the relationship between the performance of particular tasks and the characteristics of the map users (age and skills), whereas cognitive studies examine the mental processes that are supposed to underlie map use (Gregg and Leinhardt 1994). The information-processing model of cognition concerns the mental processes involved in selection, representation, retrieval, and transformation of information (Broadbent 1958); thus it provides a theoretical background for the investigation of the manner in which the map user extracts information from maps (Wood 1993; MacEachren 1995). However, as mental processes are difficult to observe, currently only a limited number of studies focusing on children as map users have been based on the information-processing model. The interest in children's mental representation of geographical space is not necessarily a new topic of observation (Drumheller 1968; Gould and White 1974; Downs and Stea 1977). Gould and White (1974) popularized the term "mental maps" in the early 1970s, and since then there has been a continuing interest in how people draw sketch maps of geographical space (Saveland 1978; Bosowski 1981; Wise and Kon 1990). In the last decade, research has focused on children's mental representations of their country or the world and examined elementary school children's freehand sketch maps (Konecny and Svancara 1996; Wiegand 1997, 1998; Nakos, Filippakopoulou, and Michaelidou 2000). Uttal and Wellman (1989, 129), conducted experiments with younger children (four to seven years of age) to examine if and when young children can acquire an integrated mental representation of space from a map. Today, assumptions on the development, selection, and use of map, and general and specific schemata, as cited by MacEachren (1995) seem to give a new impetus to research concerning children's use of maps. Map schemata, which are defined as structuring mechanisms that provide a common format for organizing sensory input of the map and long-term knowledge representations of the map user (MacEachren 1995), provide a context within which the conceptual picture derived from maps can be understood. Wiegand (2001, 2002) has already conducted an investigation of specific schemata of small-scale thematic maps with children eleven to fourteen years of age (Wiegand and Tait 1999).

Children's Ability to Interpret Symbols

According to Piaget and Inhelder (1967), the child of preoperational period (approximately ages two to seven) is capable of manipulating symbols that represent his or her environment, but the understanding of place representations and fundamental spatial concepts is restricted by limitations of preoperational thought. The child of this period has a limited understanding of fundamental spatial concepts, such as the projective and Euclidean concepts, and presents certain difficulties in conservation, classification, and ordering tasks. Downs, Liben, and Draggs (1988), investigating three- to six-year-old children's understanding of maps and aerial photographs, attributed errors in the identification of symbols concerning problems of:

- reification
- maintaining scale
- understanding perspective
- identification out of context
- inconsistency of classification

They asserted that these problems are a reflection of the limitations inherent in preoperational thinking (Downs, Liben, and Draggs 1988). They concluded that developing an understanding of the cartographic processes of abstraction, generalization, and symbolization is a lengthy and difficult achievement of kindergarten through second grade period and is not necessarily completed by the end of grade two. Anderson (1996), who examined the ability of six-year-old kindergarten children to understand symbol identification, added color, insufficient value, and contrast to maps, and more specifically, to the sources of errors mentioned by Downs, Liben, and Draggs (1988). However, Anderson (1996), along with other researchers (Ottoson 1987; Trifonoff 1995; Sowden *et al.* 1996), focused on the fact that children can identify some symbols on maps and thus credited preschoolers with the ability to identify map symbols. Sowden *et al.* (1996) investigated preschoolers' abilities to interpret a vertical aerial photograph, to identify landscape features, and to solve a navigation problem on the photo. Their conclusion was that four-year-olds have significant untaught mapping abilities. In another study, children over five years of age recognized at least some of the symbols of a rather complex road map (Ottoson 1987). Trifonoff (1995) went a step further to examine second-grade students' ability to understand the symbolization of quantitative data on thematic maps. Children perceived different methods of symbolization of quantitative or ordinal data presented on maps of different scales. Wiegand and Stiell (1996) in a study of children eight to ten years of age indicated that interpretation of map-located pictures seems to depend as much on experience of forms of representation as on direct experience of the phenomena themselves.

Despite the studies on the identification of symbols by children, the way that visual variables affect their ability still remains unclear. As Anderson (1996, 114) stated

> little research has been conducted into what, for a child, characterizes a particular map symbol. Is it the symbol's color, shape, size, the feature's function, or a combination of these? For a young child, is the parameter of size secondary to shape or color when more than one variable is used to symbolize a feature?

Blaut and Stea (1971) concluded that children five to six years of age could produce simple abstract symbols and were able to understand the role of hue in symbolization. Anderson (1996, 119) examined the role of the visual variables in the symbol identification of six-year-old children, reaching the conclusion that

> although shape may be an important variable in symbol identification, its significance varies with the nature of the map symbol (point, line, area) and presentation (pictorial, abstract).

It was observed that pictorial point symbol shape was a more important characteristic than color but could be confusing if a prototype of the referent was lacking. Abstract point symbols also presented problems in identification, which might be attributed to their complexity. Anderson discovered that shape was the most important variable for identification of line symbols for both pictorial and abstract maps. Color, and more specifically the dimension of hue, was the most significant variable for area symbols, and association of a color with particular phenomena sometimes leads to correct identification but may also cause confusion. Anderson (1996) did not examine the role of visual variables of size and value in interpreting quantitative and ordinal information. According to Bertin (1983), the visual classing of size and value steps is immediate and universal. A psychological study revealed that in early developmental stages, "big" is perceptually more than "small" and that this perception becomes more strongly organized as a child develops. However, two-year-old children consistently judge dark grey to be "more" than light grey whereas four-year-olds do not (Smith and Sera 1992). The results suggest that there still exists a need to investigate children's interpretation of the visual variables of size and value in cartographic symbolization.

Initiatives of the Study

Based mainly on Bertin (1983), each of the visual variables used in map symbols connotes a scale of measurement. In cartographic practice, differentiated visual variables (hue, shape, and orientation) are used to connote a nominal scale of measurement, whereas ordering visual variables (size, value, and chroma) are used to achieve visual ranking or "ordering" and to portray features in the ordinal, interval, or ratio measurement scale (Robinson *et al.* 1995). On the same topic, MacEachren (1994) proposed three degrees of appropriateness—good, marginally effective, poor—in matching visual variables with nominal, ordinal, and numerical data. A basic principle of the general map schema as described by MacEachren (1995, 199) refers to "graphic primitives." He defines the visual variables:

> . . . [R]elationships exist among the graphic primitives such that locations whose symbols look alike are expected to be alike in some recognizable way, locations that look different are expected to be different, and graphic primitive differences are expected to be meaningfully related to actual differences (e.g., differences can be in kind or in order/amount).

Whether children grasp that the different visual variables connote specific relationships among data or specific scale of measurements is an issue that has not been examined thoroughly.

The present study examined whether visual variables would activate schemata in children with limited cartographic experience that would enable them to use the visual variables to represent nominal and ordinal data meaningfully. Children were asked to act as cartographers and participate in the symbolization of thematic maps. The following research questions were examined:

- Do children use different symbols to represent different items/attributes?
- Which variable do they consider more appropriate for portraying nominal and ordinal data?
- How do they apply the visual variables of size and value to differentiate ordinal data? Do they use small size or light value to symbolize the least and large size and dark value to symbolize the most of a series of order data?
- Do their preferences for the visual variables vary with school grade?
- Do they prefer pictorial symbols versus abstract symbols to portray nominal data?

Methodological Approach

Students from the first to third grades (six to nine years of age) of an elementary school in Greece were selected to participate in the test. They had not been exposed to systematic cartographic activities in school, but they had developed classification and ordering schemata and they had experience in using computers. In Greece, primary education starts at the age of six (first grade) and finishes at the age of twelve (sixth grade). In the curriculum, which is the same for all Greek elementary schools, both public and private, geography is treated as a separate discipline and is taught as a subject during the last two grades. For first to fourth grade, Geography constitutes an element of a more comprehensive area of study called "Study of the Environment," which includes the observation of reality from a historical, economic-social, and physical point of view. Systematic mapping activities start at fourth grade. Drawings, diagrams, and photographs support teaching of geographical concepts to younger students. According to the curriculum, from the first grade onward students participate in classification and ordering activities mainly through Mathematics. Most elementary school students are expected to be at the concrete stage of cognitive development at which, according to Piaget theory of cognitive development, children have developed classification and ordering schemata (Piaget 1950). The curriculum also provides an introductory course in computer technology so that first graders may gain experience using a personal computer. However, many public schools have not yet been equipped with computers and are not able to offer their students such experiences.

For this study, a large-scale map rather than a small-scale map was considered to be more appropriate for young students. A large-scale map can depict more familiar entities to children in a less abstract manner, thus enhancing interpretation. Students eight to nine years of age with limited cartographic experience in school had higher performance in extracting spatial relationships from large-scale maps than from small-scale maps (Michaelidou 2001). In a study by Michaelidou, a colorful large-scale map depicting a part of a town was designed, portraying roads, green areas, buildings, block outlines, and the sea. Lettering and landform information were not portrayed in order to keep the base map as simple as possible. For the purpose of the study, five sets of point symbols were created to represent the visual variables of hue, shape (abstract and pictorial), size, and value (Fig. 1). Each set consisted of three symbols and were in color for the original study. The set representing hue consisted of a yellow, a red, and a green circle. A circle, a triangle, and a square symbol of red hue comprised the set representing the abstract shape. Three magenta circles of graduated size and three circles of different values of red comprised the other two sets. A red cross, a police car, and a fire engine, all enclosed in frames, formed the set of pictorial symbols. The visual variables used to create the symbol sets were the three most often encountered in several children's atlases that were consulted for this purpose.

A map on a computer display rather than a paper map was the preferred medium of the study for three reasons. First, working with a computer was expected to be attractive to children since the process of the study could resemble a video game, a medium that captures children's imagination as no other medium does (Kafai 1994). Second,

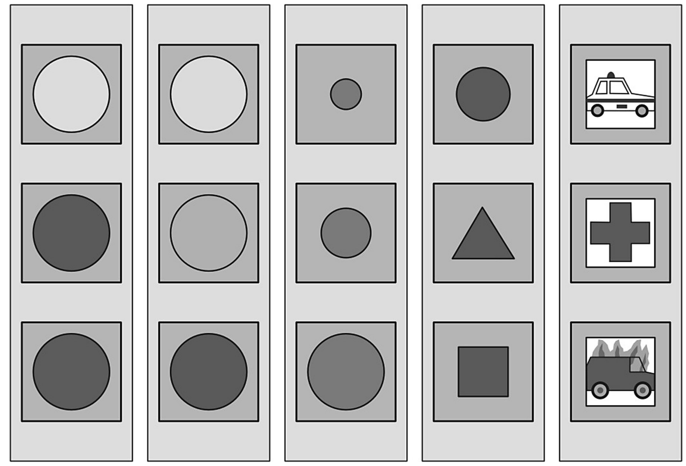

Figure 1. The five symbol sets used in the study. The original set was color coded for easy visual recognition.

Greek curriculum promotes the use of computers as teaching tools in various lessons. Third, maps on the computer display are commonplace for children today.

The participants were instructed to place the symbols they preferred to symbolize the list of items/attributes:

- museum, theatre, and church (List 1)
- police station, hospital, and fire station (List 2)
- houses of low, moderate, and high rent (List 3)
- blocks with few, many, and too many inhabitants (List 4)

Participants were assumed to know the meaning of the items and attributes since they had already encountered these in textbooks; teachers confirmed this knowledge. Also, children living in Athens are acquainted with terms such as "rent" as well as with areas with houses, apartment buildings, and multistory buildings. The contents of List 1 and List 2 refer to qualitative or nominal data. The contents of List 3 and List 4 refer to quantitative/ordinal data. For Lists 1, 3, and 4 the participants composed four thematic maps using four given sets of point symbols varying in hue, abstract shape, size, and value. For List 2 the participants were asked to compose three thematic maps using three given sets of point symbols varying in hue, shape (pictorial), and size respectively. Finally, from the three or four maps that were composed for each list of items or attributes, the participants were asked to select the map that according to them better portrayed the list. The assessment of children's responses to the test was based on MacEachren's (1994) visual variable syntactics: color hue, shape, size, and color value can be matched to nominal and ordinal data with different degrees of appropriateness: color hue is "good" for portraying nominal and "marginally effective" for ordinal data; shape is "good" for nominal and "poor" for ordinal data; and size and color value is "poor" for nominal and "good" for ordinal data.

As an easy starter, the first list to be symbolized was a list of nominal items. Other studies have shown children have less difficulty interpreting qualitative rather than quantitative data (Gerber 1984); therefore, half of the participants should symbolize List 1 first and List 2 last and the other half the opposite way. List 3 should be symbolized second by half of the participants and third by the other half. The same pattern was followed for List 4.

The Software

A software program was specially designed for the purposes of the investigation, in order to meet the needs, attitudes, and experiences of young students as users. The software was very simple to use, so performance on the test did not depend on the computer experience of participants. Its form and execution resembled a simple video game. Following contemporary trends in information technology, the software was developed using Visual Basic programming language, an object-oriented environment. In order to satisfy the requirements of the investigation, the software incorporated a short demonstration, maps, different themes, symbol sets, short instructions, and comments. These software components were transformed into graphic objects selected from the library tool supported by Visual Basic. The graphic objects used were forms for views (maps) and images (demo), command buttons for the themes and symbol sets, and texts for the instructions and comments. The control of the software graphic objects was kept as simple as possible and was done by clicking or double-clicking with the mouse. In order to minimize any possible control errors and to enhance the user interface, every action was followed by a visual effect on the selected command button, accompanied by a distinctive sound. The software development incorporated the current trends of graphical user interface (GUI) generation. An output text file was created automatically by the software containing a code number, the age, sex, grade, and the selections of symbols and maps for each user.

The Investigation

The investigation was conducted in a large private elementary school in Athens, Greece. The selected school followed the curriculum of public schools, with students coming mainly from a middle class status; facilities ensured that first grade students were introduced to computers. At the time of this study, public schools were not equipped with personal computers. In total, 106 participants from first (6.8-years-old), second (7.7-years-old) and third (8.7-years-old) grades were selected by systematic sampling. The distribution of the sample is presented in Table 1.

The investigation was undertaken during normal school hours in a small room on the school premises. Each student underwent the test individually, sitting in front of a personal computer in the presence of the investigator who described the task as a game "having to do with map composition." A personal computer with a 17-inch display was used during the test. At each stage of the test simple directions were displayed describing the execution of the tasks. The investigator read them aloud for the first graders. During the test, the investigator answered the participant's questions related to the functioning of the program and explained that the participant could do anything he or she wanted concerning the symbolization of the items/attributes. To start, each child executed a simple, short task in order to get acquainted with the functions needed for the test performance. An image of the sky was shown on the display, along with three symbols representing the sun, rain, and clouds, and the child was asked to select the appropriate symbol to portray sunny, rainy, and cloudy weather respectively. Appropriate sounds followed each selection making the test resemble a game. A typical view of the introductory task is shown in Figure 2.

After the introductory task, the map was shown on the display and the investigator described it as a representation of a small town, as seen from above. He asked the participant to point to roads, buildings, green areas, and the sea in order to examine whether the

Table 1. Distribution of sample.

Grade	First	Second	Third	Total
Boys	17	18	18	53
Girls	18	17	18	53
Total	35	35	36	106

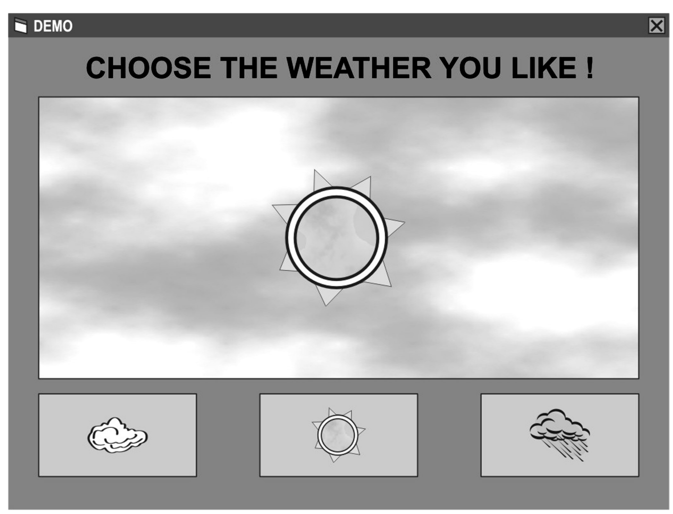

Figure 2. Introductory view of the software.

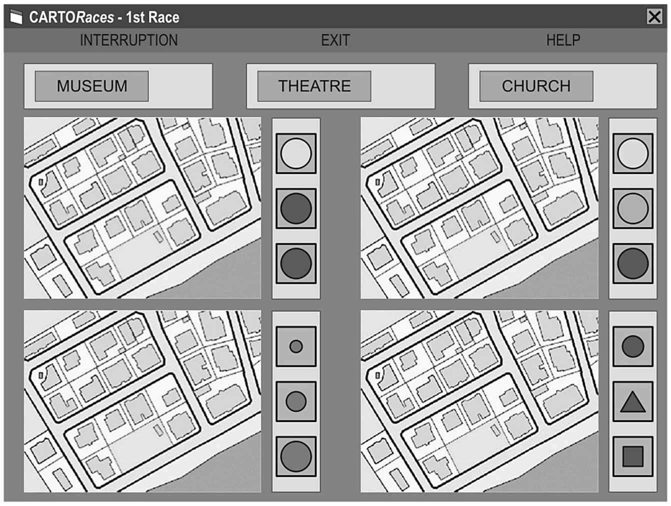

Figure 3. A typical display of the software.

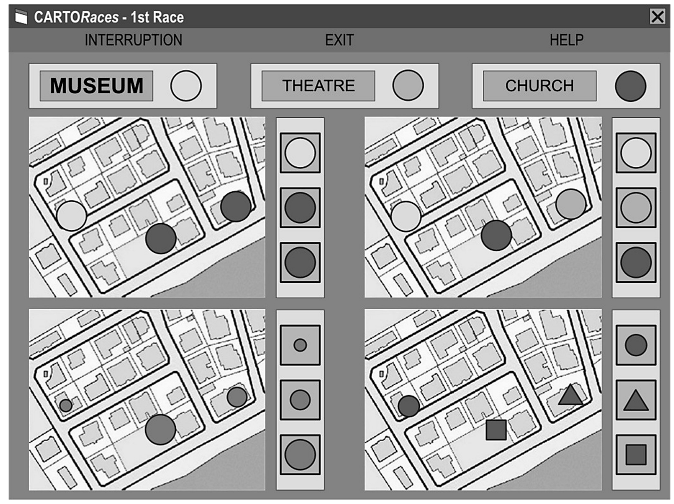

Figure 4. A typical view of the maps composed.

participant understood what the map showed. The task of symbolization of the lists of items or attributes started and directions were displayed on the screen. For example, if the items of List 1 were going to be symbolized, the following directions were displayed: "Place the museum, the theatre, and the church on the maps using the symbols." The map of the small town was displayed simultaneously four times on the screen and next to each map a different set of three symbols was displayed as shown in Figure 3. The dimensions of the map were 16 × 12.5 cm.

The three items or attributes to be symbolized were written as a heading at the top of the display. The investigator gave a simple definition for each of the symbols if the introductory conversation revealed that the student did not have a clear conception of the terms. In the case of List 3, "rent" was related to the amount of money. In the case of List 4, the blocks with "few—many—too many inhabitants" corresponded to blocks with "houses—apartment buildings—multistory buildings."

After the explanations, the participant was asked by the investigator to first select an item or attribute from the heading and then choose a symbol to show it on the map. The symbol was automatically located at a predefined position on the map. The selected item or attribute was magnified in the heading and the chosen symbol was displayed next to it, which created a legend. After the child composed the four maps for the specific list of items or attributes, the following instruction was displayed:

> You have created four maps. Choose the map that you believe best represents the theatre, the museum and the church. If you want to change any of the symbols you have used to locate the theatre, the museum or the church on any of the four maps, do so now. If you do not want to make any changes, move the mouse to that map that you choose and click the left mouse button.

The child could modify any of his or her symbol selections on any map at any time, before the final selection of the map. While moving the mouse on a different map, the child's symbol selections were displayed in the heading. A typical view of the maps composed for a list of items or attributes is presented in Figure 4. The same procedure was followed for the other lists of items or attributes. The maps and items or attributes were displayed in the same position for all tasks. The symbol sets were displayed next to the maps, but not in the same order as during the various tasks.

After the child had composed the maps for the items/attributes of all four lists and had made his/her selection, the investigator showed him/her the composed maps and asked questions such as: "Why did you choose this symbol to show the . . . (specific item)?" and "Why do you think this map shows better the . . . (specific list of items/attributes)?" The answers were recorded. All the participants reacted positively to the test and were willing to express their thoughts. Approximately 30 percent of the participants reconsidered their initial selections of symbols and made changes during the test.

Results and Discussion

Five criteria, which reflect the appropriate use of visual variables according to Robinson *et al.* (1995) or the effective use of visual variables according to MacEachren (1994), were adopted for the assessment of the results:

Table 2. Selection of various symbols for different items/ attributes.

	Hue		Shape		Size		Value	
	f	f%	f	F%	f	f%	f	f%
List 1	99	93%	98	92%	101	95%	99	93%
List 2	105	99%	106	100%	97	92%	—	—
List 3	105	99%	102	96%	102	96%	101	95%
List 4	103	97%	101	95%	106	100%	99	93%

- use of different symbol for different item/ attribute
- choice of visual variable of hue or shape to portray nominal data
- use of the visual variables of size or value to portray ordinal data
- use of ordering symbols in size or value and match small/light with lower quantity and large/dark with greater quantity to portray ordinal data; match the pictorial symbols to corresponding items

Table 2 shows the frequencies (f) and relative frequencies (f%) of students who used three variations of the given visual variable (hue, shape, size, or value) to portray each of the three different items or attributes for the four lists. For each list, almost all students from all grades (92% to 100%) used variations in visual variables to present various items/attributes and applied different symbols to represent different items/attributes.

Table 3 shows the visual variable selected by the students (frequencies f and relative frequencies f%) as the most effective for portraying the items or attributes of Lists 1, 2, 3, and 4 respectively. No statistically significant difference among the selections completed by each grade or between the selections made by boys and girls came out from the application of χ^2 test, and so the data were combined in Table 3.

For List 1 (museum, theatre, and church) half of the participants (52%) selected the visual variable of hue as the best to portray nominal data. The visual variable of value, the other dimension of color, was preferred by approximately a quarter of the participants (23%) to represent nominal data, almost double compared to those who selected shape (13%) or size (12%). For List 2 (police station, hospital, and fire station) the vast majority of the participants (96%) selected the pictorial symbols as the best means to portray nominal data. For List 3 (houses of low, moderate, and high rent), the visual variables of size (37%) and hue (38%) were dominant choices of the participants for portraying ordinal data. Especially for List 4 (blocks with few, many, and too many inhabitants), constituting the more abstract attributes, the preference of the visual variable of size (47%) outnumbered that of hue (29%) in contrast with the expressed preferences for List 1 and List 2 with nominal data.

Tables 4a and 4b illustrate the frequencies (f) and relative frequencies (f%) of students who applied the criteria in symbolization of the nominal data of List 1 and List 2 and the ordinal data of List 3 and List 4 respectively. The same results are illustrated in Figures 5 and 6 in a graphical form.

As Tables 3 and 4a show, all the children who chose the visual variable of hue to portray nominal data of List 1 and List 2 used three different hues to portray the three different items. All of the children who chose the visual variable of abstract shape to portray nominal data of List 1 used different shapes to portray different items, except for one child who used the same shape for two different items. Unexpectedly, five out of the 102 children who chose pictorial symbols to represent the items of List 2 did not match the items with the corresponding pictorial symbols. As Tables 3 and 4b show, seven children out of thirty-nine and six out of fifty who chose size to portray the attributes of List 3 and List 4 respectively did not order the symbols by size to match the quantities they portrayed. Six children out of eighteen and five out of fourteen who chose value

Table 3. Frequencies of selection of visual variables.

	Hue		Shape		Size		Value	
	f	f%	f	f%	f	f%	f	f%
List 1	55	52%	14	13%	13	12%	24	23%
List 2	3	3%	102	96%	1	1%	—	—
List 3	40	38%	9	9%	39	37%	18	17%
List 4	31	29%	11	10%	50	47%	14	13%

Table 4a. Frequencies of appropriate or effective application of the visual variables of Lists 1 and 2.

	Hue		Shape	
	f	f%	f	f%
List 1	55	52%	13	12%
List 2	3	3%	97	92%

Table 4b. Frequencies of appropriate or effective application of the visual variables of Lists 3 and 4.

	Size		Value	
	f	f%	f	f%
List 3	32	30%	12	11%
List 4	44	42%	9	8%

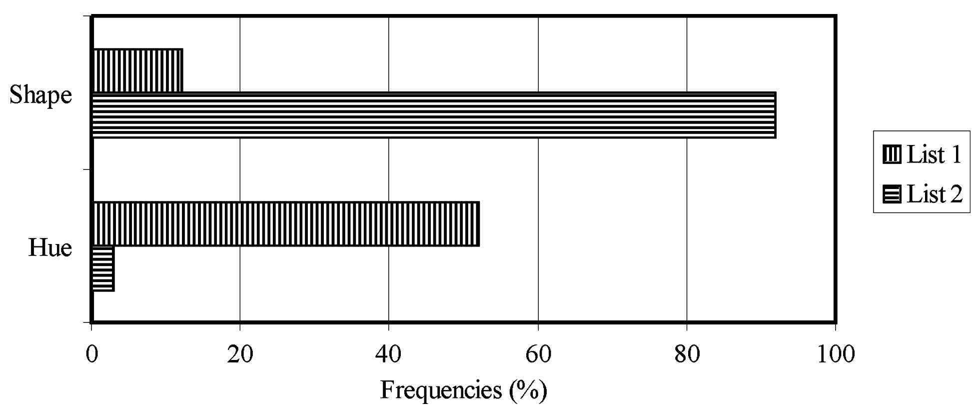

Figure 5. Graphical presentation of appropriate or effective application of the visual variables (f%) of Lists 1 and 2.

to portray the attributes of List 3 and List 4 respectively did not order the symbols by value to match the quantities they represented.

Regardless of the final selection of the most appropriate map, Tables 5 and 6 represent the frequencies (f) and relative frequencies (f%) of participants who ordered the symbols varying in size and value, and matched small size and light value with lower quantity and big size and dark value with more quantity for List 3 and List 4 respectively. In both cases the visual variable of size led more participants to order the symbols than the visual variable of value.

Children's Comments

A brief review of children's answers to the investigator, who asked them to justify their selections, is given to add more meaning to the analysis. Representative responses of children could give us a better idea of the way they associate the characteristics of the symbol with the referent. None of the participants had any problem understanding that the map used in the test represented a small town, as seen from above, and all of them could point to the roads, buildings, green areas, and the sea.

Children provided a variety of answers to justify their selection of a particular symbol to represent a specific item; most of the answers revealed an insightful approach to the symbolization task. Almost all the children remarked that they wanted to show the three items with different symbols in order to differentiate them. According to the children's comments and selections, the visual variable of hue is more prominent than abstract shape, value, and size. Some of the children selected hue even to present ordinal data. A characteristic response was given by a second-grade girl: "I used three different colors to show the theatre, the church, and the museum. I think color symbols make them look more different than the other symbols." Some children selected the symbols based on their personal preference: "The map becomes more attractive with color."

Activating mental images, red hue was often associated with fire or the red-cross sign, and children selected red hue to represent a fire station or hospital respectively. Evidences of reification were revealed in their responses, as was observed in symbol identification in other studies (Downs, Liben, and Draggs 1988; Anderson 1996). For example, a second-grade girl remarked that: "There is no white color to symbolize the hospital." Other children selected a hue with more subjective criteria. A characteristic response was given by a first-grade girl: "I like museums and my mother likes yellow, so I choose yellow."

The participants did not have any problem associating pictorial symbols with their referents. For abstract shape, some children said that the association of the different shapes with the three items served only to differentiate the items. Yet others justified their choice by saying "because it looks like that," a common reply given by kindergarten children during symbol identification task (Anderson 1996). A second-grade student represented both the museum and the theatre with a square and the church with a circle. He said:

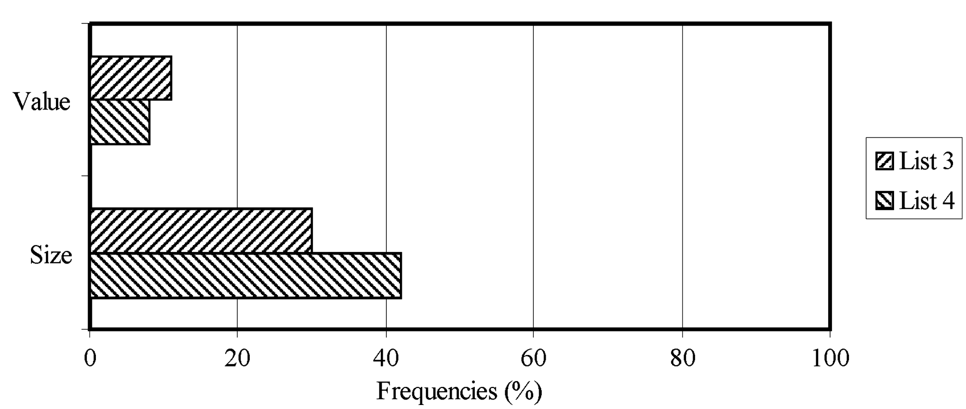

Figure 6. Graphical presentation of appropriate or effective application of the visual variables (f%) of Lists 3 and 4.

Table 5. Ordering of symbols: List 3.

Grade	Size		Value	
	f	f%	f	f%
First	24	69%	18	51%
Second	17	49%	19	54%
Third	29	81%	20	56%
Total	70	66%	57	54%

"Maps show things from above and the buildings look like squares whereas a church looks more like a circle." The circle was quite often chosen for the church because of its shape as most of the Greek churches have impressive circular domes. A triangle was selected by a first-grade girl to represent the museum because, she said, "It reminds me [of] the roof of the museums," suggesting the shape of pediment. A peculiar answer expressing more abstract thinking was given by a second-grade girl who selected the circle for church: "It is a place of gathering."

Most of the children set up levels of relative importance in both qualitative and quantitative data and tried to achieve visual hierarchy not only by applying size and value but also by applying the visual variables of hue and shape. The majority of the participants associated red hue with importance, bigger size, and more quantity or the "upper-class," whereas quite often they connected green hue with "lower-class" and yellow with "middle-class." Children who tried to set a visual hierarchy in shape usually regarded the circle as the most important shape, followed by the square and the triangle. A second-grade girl selected red hue for the higher rent and green hue for the lower rent stating simply that: "Red means more quantity."

When ordering variables, the majority of children associated "small circle" with "low rent" and "few inhabitants" and "big circle" with "high rent" and "too many inhabitants." A characteristic comment was given by a third-grade boy: "Small size matches with little money and big size with much money. So I chose small symbol for low rent and big symbol for high rent." Approximately half of the participants associated "light color circle" with "low rent" and "few inhabitants," and "dark color circle" with "high rent" and "too many inhabitants." A first-grade girl said: "Dark color matches to more quantity so I chose it for too many inhabitants." A first-grade boy selected the bigger circle from the set of graduated symbols to represent the hospital because as he said: "When you need a hospital you have a great need for it," associating 'big' with 'important."'

Table 6. Ordering of symbols: List 4.

Grade	Size		Value	
	f	f%	f	f%
First	26	74%	18	51%
Second	26	74%	15	42%
Third	32	89%	23	64%
Total	84	79%	56	53%

It is possible that many of the peculiar explanations given by children for their selections were expressed just to satisfy the demands of the task and as a response to the investigator's questions. For example, from a cartographic viewpoint, there is no explanation why one uses red or yellow hue for the museum. Feeling that they had to justify all their selections, the participants might have invented more subjective reasons. It was difficult for children of six- to nine-years-old to eloquently express that symbols of different hue or different shape can represent arbitrarily nominal data and that symbols of different size and value can represent hierarchically ordinal data.

Conclusions

This study examined how first to third graders (six to nine year old) of an elementary school use the visual variables of hue, shape (abstract and pictorial), size, and value to represent nominal and ordinal data on thematic maps.

Children from the first to third grade of elementary school who had not been exposed to any systematic cartographic activities in school, using specially designed software, participated in the design of thematic maps at the stage of symbolization, and expressed their preferences towards the application of different visual variables. All the participants were able to understand that the task-map displayed a part of town as viewed from above to recognize the different entities presented on the map and the majority of them could use symbols to represent different items in a meaningful way. The responses of children revealed that they had developed a general map schema at an early age, prior to the start of formal education (Kulhavy and Stock 1996).

This study shows that children—even from the first grade—used different symbols to represent different items or attributes. Additional research needs be done on this topic to examine children's responses when the same item or attribute is presented more than once on the map.

Children of first, second, and third grades showed preferences for specific visual variables in portraying nominal and ordinal data. Students from the different grades did not show different attitudes toward visual variables. No difference between boys' and girls' attitudes was found. An interesting result is that a significant majority of the participants used the visual variables of hue or shape to represent nominal data. Their selection is in accordance with standard cartographic practice. The shape character—either abstract or pictorial—determined the dominance of hue or shape in children's preferences.

Between hue and abstract shape the majority of children selected hue as the best visual variable to portray nominal data, but when required to choose between hue and pictorial shape, the visual variable of shape was dominant. Another interesting result is that the majority of children considered the visual variable of size as the most appropriate for symbolization of ordinal data and the least appropriate for symbolization of nominal data. Taking into account that the children did not have any systematic cartographic experience and acted mainly by intuition, the viewpoint that size is "good" for symbolization of ordinal data is verified. On the other hand, approximately half of the participants chose the visual variables of size or value to portray ordinal data. Their preferences are in accordance with standard cartographic practice; however, the visual variable of hue, characterized as "marginally effective" for ordinal data (MacEachren 1994) was selected by quite a few children. It is unclear why several children preferred hue instead of value for ordinal data. Children's justifications for these selections were: "It fits better," "I like it more," or even "Color shows better the differences." A possible explanation of such a finding is that value of a color can be confused with hue. An indirect result of this study is a recognition that more research needs to be done in this area by using a grey tone scale.

By examining how children applied the visual variables of size and value to portray ordinal data, it appears that size and value activated schemata of ordering to children. The majority of children in first to third grades ordered the symbols varying in size and value and matched the small size/light value with small quantity and big size/dark value with large quantity. The visual variable of size activated ordering schemata to more children and its application in symbolizing ordinal data was more successful than that of the visual variable of value, especially in the case of more abstract data. The results of this study are in accordance with the psychological study of Smith and Sera (1992), which showed that very young children more commonly judge "big" rather than "dark" as "more." From a cartographic point of view, the results justify the concept that size and value are ordered visual variables. It must be mentioned that from the children who ordered the visual variables of size and value according to the quantity they represent more than half chose a map as more suitable to represent ordinal data. For the rest, it might have been difficult to go a step further and select the variable that would reveal the relationships among the items rather than insist on their own preferences.

According to the expressed preferences of children, pictorial symbols are very popular as well as abstract symbols varying in hue. Abstract geometrical point symbols were the least preferable symbols despite children's familiarization with simple geometrical shapes through mathematics. Whereas abstract symbols pose interpretation problems to young children (Downs, Liben, and Draggs 1988; Anderson 1996), pictographic symbols give the map a light, childlike appearance (Muehrcke and Muehrcke 1998) that justified children's preference on the map with the pictorial symbols. Gerber (1984), examining children's free recall sketch maps of their school grounds, also showed that children at a mean age of 13.1 years made regular use of abstract symbols and color to discriminate between symbols, whereas younger children (8.9 years) drew a mixture of symbols, children 10.1 years had a greater inclination to mimetic symbols, and children 11.5 years drew only mimetic and abstract symbols. In the present study, almost all the children allocated the appropriate pictorial symbol to each of the nominal items. However, it would be interesting to examine the way in which children would interpret these symbols presented on a thematic map because, as Wiegand and Stiell (1996) discovered, children appear to understand very early that pictures, signs, and symbols are metaphors for other activities but they do not have the experience to apply the appropriate metaphor to specific circumstances.

Children's responses to the tasks and their oral explanations revealed the activation of map schemata. More obvious was the understanding of a basic principle of the general map schema as cited by MacEachren (1995), which concerns the "graphic primitives" or visual variables. Although these children had not been exposed to systematic cartographic activities, they chose different visual variables in the symbolization process of nominal and ordinal data. Most children used the differences in visual variables in a meaningful way, relating them to the differences in kind or order of the items or attributes. They set up levels of relative importance mainly concerning ordinal data and tried to achieve visual hierarchy with the size of symbols and, to a lesser extent, with the value. The results of the study were in agreement with other studies, which showed that even from early grades children can interpret symbols representing nominal and ordinal data with some limitations (Downs, Liben, and Draggs 1988; Triffonof 1995; Anderson 1996).

Although the evidence of the present study is limited, it can support that from early elementary school grades students can be introduced to the concept and application of visual variables to form cartographic symbols. Thus, thematic maps can "serve" as a teaching topic as well as teaching aids in early elementary grades. Those who design maps for children should take into consideration the way different visual variables activate classification and ordering schemata to children, as well as the preferences of children towards visual variables. The study can be expanded to examine the way children react to the application of visual variables in line and area symbols.

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