INTERNATIONAL GEOGRAPHICAL UNION
COMMISSION ON GEOGRAPHICAL EDUCATION

in association with

INTERNATIONAL CARTOGRAPHIC ASSOCIATION
CHILDREN AND CARTOGRAPHY COMMISSION

SYMPOSIUM PROCEEDINGS

Expanding Horizons in a Shrinking World

UNIVERSITY OF STRATHCLYDE - FACULTY OF EDUCATION

GLASGOW, AUGUST 13 – 15, 2004

APPLICATION OF VISUAL VARIABLES IN PORTRAYING NOMINAL ORDINAL AND NUMERICAL DATA BY SCHOOL STUDENTS

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INTRODUCTION

If we look at the Greek textbooks of geography we will find there all kinds of spatial information accompanied with maps that visualise it: general reference maps and thematic maps of various types like isarithmic, isoplethic, choropleth, graduated point symbol representations and maps with abstract and pictorial symbols. But do we really know if students understand these maps and assimilate the geographic information they represent? Do we know if students understand map symbolisation and how visual variables are applied to differentiate map information?

Studies focused on children's ability to identify symbols from maps, credited pre-schoolers with the ability of map symbols identification (Anderson 1996; Sowden *et al*. 1996). Trifonoff (1995) cited that second grade students perceived different methods of symbolisation of quantitative/ordinal data presented on thematic maps of different scale. From the other hand Downs *et al*. (1988) supported that developing an understanding of the cartographic processes of abstraction, generalisation and symbolisation is a lengthy and difficult achievement that occupies the kindergarten children through secondary period and it is not necessarily complete by the end of grade two. Filippakopoulou *et al*. (1999) examined the use of primary graphic elements in map design by first and second grade students and suggested that students from early primary school can be easily introduced to the concept of visual variables and their employment in forming cartographic symbols. Exploring children's ability (aged 6 to 15 years) to categorise and symbolise, Filippakopolou *et al*. (2002) found that at the age of nine most of the children could symbolise the same feature presented more than one time on the map with the same symbol. A precedent process of categorisation of geographical features referred to by names enhanced children's ability, especially from the age of eleven and above, to categorise geographical features on maps. The researches pointed out the trend of the subjects to relate the hue of the symbols with the referent (Filippakopolou *et al*. 2002), a reaction that was met in symbol identification by younger children (Anderson 1996; Downs *et al*. 1988). Gimeno and Bertin (1983) described a teaching method that children aged ten and eleven discovered by themselves one of the fundamentals of graphic semiology, the concept of visual order. On the other hand, researches with older students revealed problems in their understanding of map symbols. Gerber (1984), examining the development of competence in cartographic language by children at the concrete level of map-reasoning (ages 8 to 14 or 15 years), determined their difficulties in comprehending quantitative signs. Wiegand and Tait (1999), who invited students aged 11 to 14 years to construct a series of thematic point symbols maps using a specially designed software tool, concluded that "many, perhaps most, students in lower and middle secondary school have only a partial grasp of how small scale thematic maps 'work'." In a more recent research Wiegand (2003) examined students (aged 14 to 17) understanding of choropleth maps and he pointed out the need for promoting better student understanding of what the mapped data mean including the directionality and numerical characteristics of choropleth maps. How students perceive the conventions in the application of visual variables in map symbolisation is still an open research topic.

This study examined how students (aged 14-15 and 17-18 years) applied the visual variables of hue, size and value to represent nominal, hierchical, ordinal and numerical data on thematic maps using point symbols. Their responses were evaluated whether they corresponded to the established application of these visual variables in cartographic symbolisation (Bertin 1983; MacEachren 1994). The participants were invited to act as cartographers at the stage of symbolisation. This method, which was applied in many relevant studies, was considered to be more motivating for the students than map reading tasks and also gave them the opportunity to reveal their preferences (Bausmith and Leinhardt 1998; Wiegand and Tait 1999; Wiegand 2003; Filippakopoulou *et al*. 1999; 2003).

METHODOLOGY

A total of 64 students at two different age levels (14-15 years and 17-18 years) participated in the study (Table 1). The students were drawn from two public schools in Athens. The first school was located in the centre of Athens and the students came from families of low or middle socio-economic status. The second school was located in a suburb of Athens and the students came from families of middle socio-economic status. None of the students involved had received any direct teaching about map at the current school year. During the geography courses on previous years they had not received any theoretical knowledge on cartographic symbolisation or map syntactics.

Table 1: Sample description

	Sex		Total
	Male	**Female**	
14-15 years	18	18	36
17-18 years	15	13	28
Total	33	31	64

The test material consisted of three maps and two sets of symbols. A large-scale (1:2,500) base map of a built-up area was designed portraying roads, parcels and buildings. Three hierarchically ordered features related to education (elementary school, high school and lyceum) and three hierarchically ordered features related to health (infirmary, clinic and hospital) were written on buildings on a copy of the base map, defining the nominal map (map A). Three ordinary scaled features related to education (school with few, many and too many students) and three ordinary scaled features related to health (small, medium and big hospital) were written on buildings on a second copy of the base map, defining the ordinal map (map B). Finally, three numerically scaled features related to education (school with 10, 15 and 20 classrooms) and three numerically scaled features related to health (hospital with 50, 150 and 250 beds) were written on buildings on a third copy of the base map, defining the numerical map (map C). Next to the name of each feature a cross sign was drawn in order to show to the participant where to locate the symbol. The maps were printed in grey-scale and they were laminated with clear plastic. Their dimensions were 28x33cm.

Two sets of symbols were designed for the study. The first one (symbol set H-S) consisted of six equal-sized squares (10mm) varying in hue (brown, blue, magenta, green, yellow and red) and three series (a brown, a blue and a green) of six squares gradually varying in size (from 5-17.5mm). The second (symbol set H-V) consisted of six equal-sized squares varying in hue (brown, blue, magenta, green, yellow and red) and three series (a brown, a blue and a green) of six equal-sized squares (10mm) gradually varying in value (from light to dark). There were available ten pieces of each symbol per set. All symbols were laminated with clear plastic.

Each student was interviewed individually in a classroom at his/her school. All the participants had to compose six maps using the two symbol sets (H-S and H-V). At the beginning of the test, the interviewer explained to the student that the test aimed at the improvement of school maps. Then the student was asked to read carefully the six features written on the map and to symbolise each one of them using the available symbol sets according to his/her preferences. Half of the participants started with the H-S symbol set to compose the three maps (A, B and C) and then used the H-V symbol set to compose the same maps. The other half of the participants used the symbol sets with opposite order. The maps were given to the students in random order. After the composition of each map the student was asked to justify his/her choices. For each participant, the choices, as well as all the justification stated, in relation to the six map compositions were recorded.

RESULTS AND DISCUSSION

The maps composed by students were evaluated on the basis of the differentiation of the nominal hierarchical, ordinal and numerical character of the given features through the application of visual variables. Table 2 refers separately to the two cases that the visual variables of hue/size or hue/value were available for the composition of the maps A, B and C and illustrates the percentages (%) of students, who used the visual variable of hue to differentiate the two themes (education and health); who used symbols of six different hues to symbolise each one of the six features (written in parenthesis); who did any other combination of visual variables which did not reveal the conception of grouping the features in nominal scale.

Table 2: Results (%) of nominal differentiation (maps A, B & C)

Symbol Sets	**Applied visual variable**	**Map A**		**Map B**		**Map C**	
		14-15 years	**17-18 years**	**14-15 years**	**17-18 years**	**14-15 years**	**17-18 years**
H-S	**Hue**	56 (+22)	54 (+28)	64 (+3)	75	69 (+3)	71
	Other	22	18	33	25	28	29
H-V	**Hue**	56 (+22)	64 (+14)	67 (+3)	75	69 (+6)	75
	Other	22	22	30	25	25	25

Table 3 refers separately to the two cases that the visual variables of hue/size or hue/value were available for the composition of maps A, B and C and illustrates the percentages (%) of students who used symbols of adjacent colours of the spectrum, symbols of increasing size, and symbols of increasing value to represent the hierarchical, ordinal and numerical character of the features; who used symbols of different hues with increasing size and symbols of different hues with increasing value to represent the scale of measurement; who did any other combination of visual variables which did not reveal the conception of the scale of measurement. In Table 3, columns E and H refer to the themes of education and health respectively.

A high percentage of students (more than 68%) of both age levels used the visual variable of hue to portray nominal differentiations in data in each of the six map composed. However the percentage of students (18-30%) that did not associate any visual variable with data differentiations is surprisingly high. Of interest is th fact that for a considerable percentage of students (14-28%) it was more important to emphasise the difference between the six different features by applying six different hues than to portray the nominal difference between the two themes (education and health) in map A. As a result the percentage of students who showed evidently the hierarchical differentiation of data in map A was lower than the percentage of students who displayed the ordinal or numerical differentiation in maps B and C respectively in both cases that symbols sets of hue and size or hue and value were available. This result can be explained by the fact that hierarchical order was not lexically expressed.

Table 3: Results (%) of hierarchical, ordinal and numerical differentiation (maps A, B & C)

Symbol Set	**Applied visual variable**	**Hierarchical (Map A)**				**Ordinal (Map B)**				**Numerical (Map C)**			
		14-15 years		**17-18 years**		**14-15 years**		**17-18 years**		**14-15 years**		**17-18 years**	
		E	**H**	**E**	**H**	**E**	**H**	**E**	**H**	**E**	**H**	**E**	**H**
H-S	**Hue**	6	3	4	7	-	3	-	4	-	3	-	7
	Size	36	39	54	36	50	58	68	71	58	64	64	54
	Hue & size	-	-	-	-	6	3	-	4	3	3	-	4
	Other	58	58	42	57	44	35	27	21	39	30	36	35
H-V	**Hue**	8	8	6	7	-	6	-	4	3	-	-	-
	Value	33	31	54	43	56	47	68	57	56	53	64	61
	Hue & value	-	-	-	-	6	6	7	7	6	6	-	4
	Other	58	61	40	50	38	41	25	32	35	41	36	35

The average percentages (%) of the students who applied hue to differentiate nominal data in all maps and size and value to differentiate ordinal and numerical data in maps B and C respectively are presented in Table 4. As it comes out the majority of students made selections that correspond to the cartographic syntactic rules. Almost 75% of the students associated the nominally differentiated data with hue. The quantitative data was symbolised 60% by size and 58% by value. There is a difference in the performance between the two age levels, as Table 4 shows, especially in the application of size and value. Of interest is the fact that size and value were applied almost equally for the symbolisation of quantitative data, although size is the normal differentiating visual variable for such data (Dobson 1993; Smith and Sera 1992) and it was expected in this study to be applied more successfully than value.

Table 4: Average percentages (%) of the applied visual variables according to cartographic conventions

Age	**Visual variables**		
	Hue	**Size**	**Value**
14-15 years	73	58	53
17-18 years	76	64	63

From the available hues 19 students (30%) chose the blue hue for the education and 23 students (36%) the red hue for health features. With comments like “red reminds me blood, danger” and “blue reminds me the Greek flag or innocent” they justified their choices; comments similar to those of younger children in symbolisation or symbol identification tasks (Anderson 1996; Downs *et al*. 1988; Filippakopoulou *et al*. 1999; 2002). Another comment refers to the application of dark values as appropriate for “bigger, more important, more difficult, more necessary, more serious”.

CONCLUSIONS

The results of the study indicate that the majority of students (aged 14-15 and 17-18 years) applied the visual variables of hue, size and value to represent nominal, ordinal and numerical data on thematic maps using point symbols in accordance to the conventions of cartographic symbolisation. Nevertheless, taking into account that the participants had completed the geographical courses of the obligatory education and they had been exposed to many types of thematic maps, and also the satisfactory performance of students of elementary school at the application of visual variables (Filippakopoulou *et al*.; Gimeno and Bertin 1983), the number of students that failed to differentiate the data according to the cartographic syntactic rules is considered to be rather high. It seems that although students are ready to understand the syntactic rules of symbolisation they have to be taught in order to apply them.

REFERENCES

Anderson, J.M. 1996. What does that little black rectangle mean?: Designing maps for the young elementary school child. In *Cartographic Design: The Theoretical and Practical Perspectives*, ed. C.H. Wood and C.P. Keller, pp. 103-124. Chichester: Wiley and Sons.

Bertin, J., 1983. *Semiology of Graphics: Diagrams, Networks, Maps*. Madison: University of Wisconsin Press.

Bausmith, J.M., and Leinhardt, G. 1998. Middle-School Students’ Map Construction: Understanding Complex Spatial Displays. *Journal of Geography*, 97(3): 93-107.

Dobson, M.W. 1983. Visual Information Processing and Cartographic Communication: The Utility of Redundant Stimulus Dimensions. In *Graphic Communication and Design in Contemporary Cartography, Volume 2, Progress in Contemporary Cartography*, (Ed. D.R.F. Taylor), pp. 149-175. Chichester: John Wiley and Sons.

Downs, R.M., Liben, L.S., and Draggs, D.G. 1988. On education and geographers: The role of cognitive developmental theory in geographic education. *Annals of the Association of American Geographers,* 78(4): 680-700.

Filippakopoulou, V., Michaelidou, E., Nakos, B. 1999. The use of primary graphic elements in map design by first and second grade students. Proceeding on the Joint Seminar on Discovering Basic Concepts, ICA, Montreal, Quebec, Canada, pp. 58-63.

Filippakopoulou, V., Nakos, B., Michaelidou, E. 2002. Exploring children's ability to categorize and symbolize. In: *Cartografia para Escolares no Brazil*. Belo Horizonte: CD-Rom.

Gerber, R. 1984. The development of competence and performance in cartographic language by children at the concrete level of map-reasoning. *Cartographica*, 21(1): 99-119.

Gimeno, R., and Bertin, J. 1983. The cartography lesson in elementary school. In *Graphic Communication and Design in Contemporary Cartography, Volume 2, Progress in Contemporary Cartography*, (Ed. D.R.F. Taylor), pp. 231-256. Chichester: John Wiley and Sons.

MacEachren, A.M., 1994. *Some Truth with Maps: A Premier on Design and Symbolization*. Washington, D.C.: Association of American Geographers.

MacEachren, A.M., 1995. *How Maps Work. Representation, Visualization, and Design*. New York: The Guilford Press.

Smith, L.B., and Sera, M.D. 1992. A Developmental Analysis of the Polar Structure of Dimensions. *Cognitive Psychology*, 24: 99-142.

Sowden, S., Stea, D., Blades, M., Spencer, C., and Blaut, J.M. 1996. Mapping abilities of four-year-old children in York, England. *Journal of Geography,* 95(3): 107-111.

Trifonoff, K. (1995). Going beyond location: Thematic maps in the early elementary grades. *Journal of Geography,* 94(2): 368-374.

Wiegand, P. 2001. Children's mental representation of small scale thematic maps. Proceedings of the *20th International Cartographic Conference*, August 6-10, Beijing, China, Vol.5, pp. 2972-2978.

Wiegand, P. 2003. Using GIS to access school students understanding of chorpleth maps. Proceedings of the *21th International Cartographic Conference*, August 10-16, Durban, South Africa, pp. 506-514.

Wiegand, P., and Tait, K. 1999. Promoting children's collaborative learning in cartography with a software mapping tool. Proceedings of the *19th International Cartographic Conference*, Ottawa, Canada, Vol.1, pp. 499-505.