12

Vassiliki Filippakopoulou, Evanthia Michaelidou, Byron Nakos

A STUDY OF CHILDREN'S PERCEPTION OF CARTOGRAPHIC LANDFORM REPRESENTATION

Cartography Laboratory, Department of Surveying, National Technical University of Athens
9, Heroon Polytechniou STR., Zographos, GR-157 80, Greece
e-mail: bfilippa@survey.ntua.gr; e.michaelidou@cytanet.com.cy;
bnakos@central.ntua.gr

Abstract. This paper presents the ways different methods of landform representation are read and interpreted by primary school students. In this study four different methods of representing landform are examined: contours, hypsometric tints, oblique hill shading and a combination of hill shading and contours. Each method was used to represent the landform of a common area, which also contained other information typically found on topographic maps. For each map a set of questions was composed with the goal of asking the students to extract the same kind of information regardless of the map type. Students' understanding of the landform information as well as their comprehension of the fundamental elements of the geographical space were examined. The test results were statistically analysed and discussed. Of particular interest are the suggestions that have application for both cartographers designing school maps and primary school teachers of Geography and Environmental courses.

INTRODUCTION

Although the interpretation of landforms has been investigated for centuries it remains an important research topic. Landform is an important geographical phenomenon and is frequently a significant map element. The three-dimensional nature of landform makes it difficult to portray without effecting the legibility of the map. Most of the experimental studies that have investigated landform representation and its interpretation have used high school and more often college students as test subjects. A review of these studies reveals that, even at this age, many of these respondents encounter problems in the interpretation of landforms. It appears that the contour line, the most commonly used method of landform representation, is difficult to recognize and interpret by non-experienced map-readers. Starting from this point, one might not be very optimistic about testing primary school students on such a topic. Well, the

ISBN 83-85582-94-0

answer to this doubt was given by one eleven year old subject in the present research, who mentioned, after listening to the definition of contour lines: "So, if contours are close together, that means the ground is steep and..."

Landform representation on maps

Humans conceive the earth's surface, its landform, as a geographical phenomenon having a three-dimensional continuous character. The three-dimensional component of landform is difficult to present on a two-dimensional medium (i.e., maps or displays) in a manner that ensures that graphical and communication distinctiveness can be achieved. In addition, the preservation of the continuous character of landform produces conflicts with the planimetric details portrayed on maps. Thus, the method of landform representation is crucial for the quality and intelligibility of the map.

To portray landforms on contemporary maps one or a combination of the following methods of representation is applied:

- Contour lines (isarithmic mapping),
- Hypsometric tints (ordinal scale) and
- Oblique hill shading (continuous statistical surface).

Representing landforms by contour lines provides the map users with accurate metric information [10], preserves the continuous character of the earth's surface and gives its abstract morphology -- by the density of the contour lines. Although this method is widely utilised on topographic maps, its interpretation is difficult without any engineering knowledge [3].

Hypsometric tinting is a more "user friendly" method of landform representation. It groups a finite numbers of contours with the application of an area symbol -- producing a series of different coloured zones. This method, which is widely used on wall maps, atlases and "physical" maps, satisfies most of the landform requirements of the general map reader [10]. It is the most common method of landform representation encountered by children on school maps.

Hill shading is the tonal representation of the shadows as they occur on a relief surface under oblique light [4]. A true interpretation of the landform morphology is provided if the "artificial" lighting source is directed from the northwest of the mapped area. Hill shading presents landform in an intelligible way, even for the inexperienced map user. The combination of hill shading with the representation of other planimetric details, especially with area symbols, does not produce conflicts. Although, in the past, hill shading was a difficult method to be applied, today it is becoming rather easy due to the availability of various popular computer software packages, and the existence of Digital Terrain Models (DTM's) [12].

The ability of children to interpret the three-dimensional space

Children's conception of space develops sequentially, from the simple topological relationships to the more difficult conception of projective and Euclidean space [8]. By the age of seven or eight, at the beginning of operational period (seven to eleven years), children have already acquired most of the projective relations, which involve straight lines, and perspective and some Euclidean relations. By the age of eleven or twelve, when they have reached the formal period, children develop an understanding of Euclidean space which involve among other the notion of co-ordinate system. These concepts are prerequisites for understanding three-dimensional space. However, even for adults, conceiving the shape of three-dimensional landforms from a two-dimensional map is a difficult task.

Maps for children and landform representation

From a brief review of the literature on the effect of the various types of landform representations on the map legibility some interesting results can be identified. These are presented here.

In school maps, landform is usually depicted through hypsometric tints. Children learn to associate the colour green with plains, yellow with hills and brown with mountains. A study by Patton and Crawford, involving subjects, who ranged in level from primary Grade 6 to college level, indicated that: "hypsometric maps using spectrally ordered colours accurately transmit data concerning topographic elevation, but also transmit inaccurate unintended information... (p. 126)" [6]. Furthermore, it has been found that hypsometric colour may mislead the map user to visualise a terraced landscape [11], or to associate the colours with other phenomena, for example a brown hue with little rainfall [6]. The concept of landform representation by means of contour lines is usually introduced to children when they have reached the formal period (eleven to twelve years of age). But even at this age, students appear to have difficulties in grasping the concept of contour lines [1]. Sandford describes three stages in the process of visualising the three-dimensional landform from the contour lines [11]. According to him, young children learn to perceive contours, to imagine slope and then to put slopes together mentally to visualise the terrain. During the first stage children perceive two-dimensional patterns of contours which are closely spaced and parallel, or forming circles. When they reach the second stage they begin to interpolate mentally the space between the contour lines. They realise that contours imply slope and their density implies steepness. Finally, they distinguish particular landforms such as spurs and valleys. At the third stage, they can see that the elements making up the terrain form regional patterns and apply correct terms to describe them.

De Lucia states that using a contour map results in greater map information accessibility relative to the shaded relief map [2]. According to the same author: "the shaded relief terrain increases the time required to visually perceive and process elements of non-terrain information (p. 17)". In a study by Phillips *et al.* [7] the legibility of four different types of relief map (contour maps, contour with hill shading, hypsometric layer tints and spot height maps) is compared. The results show statistically significant differences between the four types of maps, but none of them could be considered the best for all the questions. In the same study, layer tints were identified as the best method for estimating relative heights and recognising the landscape, while contour line maps (with or without shading) had the same performance. In a similar study contour lines were supplemented with layer tints on one hand and hill shading on the other [9]. The results of this study concluded that contour lines supplemented with layer tints gave the best results in timing the responses, while hill shading gave the poorest scores. The study of greatest relevance to our study is that conducted by Wiegand and Steill [13], since they tested primary school children's ability to interpret four model landscapes of increasing complexity. The results of their study show:

"an age-related progression from representing hills in elevation only, through simple outline plans and various attempts to differentiate slope, to their early experiments with the use of contours (p. 179)". Also according to the same authors: "children's understanding of the relationship between landscape and map remains relatively unexplored (p. 190)" and they suggest that: "teachers can support children's understanding of relief mapping by acknowledging children's own prior cartographic thinking and making strategic use of maps employing hill signs other than contours (p. 179)".
This provides a rational for examining the topic of hill shading as a visualisation method which "imitates" the nature of terrain.

THE PRESENT RESEARCH

Aims

There are two aims of the present study: to determine the age by which children can be introduced to the four previously mentioned different methods of landform representation and; to examine the effect of these alternative methods on the reading and interpretation of the planimetric and hypsometric map content. It is our belief that children need to be acquainted, at the earliest possible age, the various kinds of maps that they will use when they will grow up. Therefore, the test materials (maps and questionnaires) were designed to meet the objectives of map use as they follow cartographic principles. For this reason the designed maps are similar to a typical topographic map. The landform representations are those usually encountered in mapping. The test questions relate to the interpretation of the fundamental elements of the geographical space, and include both planimetric and landform information.
In Greece, primary students in the first and second grade encounter the vocabulary associated with landscape in social studies. In Grade 3 (operational period) the students are introduced to mapping activities. The subjects in this study were primary school children, of the Attiki Prefecture, eight to eleven years of age.

Maps

Four general maps of the Attiki Prefecture at a scale of 1:500,000 were designed. An area familiar to most of the children was selected so that the time would not be lost in interpreting the geographical space as a whole. Each map combined three layers of information:
Landform information, which was portrayed differently on each map and comprised the background layer of each of the maps.
Planimetric information, which included features such as boundaries, roads, towns, villages, rivers etc. This was portrayed in the same way in all maps.
Lettering of places and features. This was the foreground layer and was identical on each of the maps.

The four different methods of representing landform which used were:
i) <u>Contour lines</u> (Figure 1).
Contour lines were depicted using brown lines with an interval of 200 m on an ochre background. Index contour lines were numbered.

ii) Hypsometric tints. (Figure 2).
Hypsometric zones were portrayed by conventional tints (green for plains, yellow for hills and brown for mountains). The hues of green, yellow and brown, used for the tint symbolisation, were chosen because: they are the hues most commonly used for the symbolisation of hypsometric tints; they are spectrally ordered and; are familiar to children as they are commonly used in school atlases and school wall maps.

iii) Oblique hill shading (Figure 3).
The hill shading representation (gray tones) was chosen as the most suitable for giving a perspective image of the landscape. The lighting source was directed northwest of the map area with a slope of 45°.

iv) Combination of hill shading and contour lines (Figure 4).
All the maps contain spot elevations. A brief reference to the planimetric layer portrayed on the maps is given. The following symbolisation is used: towns are represented by area symbols, black point symbols portray villages, a black point symbol with a cross on the top indicates monasteries, pictorial symbols are used for archaeological sites and airports, red lines of different widths for the three classes of roads, a black and white line indicates a railway, and a dashed-dot line for prefecture boundaries. Rivers, streams, lakes and the sea are blue. The location of all the lettering followed the basic cartographic rules of names placement. The lettering employed indicated the place names of villages, rivers, mountains, bays, etc. Each map has a title, scale, north arrow and legend. Photocopying was used to reproduce all the coloured maps.

Questionnaires

Four questionnaires, one for each of the different landform maps, were formulated. Each comprises eleven questions. The first seven questions, common to all the questionnaires, examined spatial relations that were not pertinent to landforms. These questions were intended to evaluate the children's ability to define topological relationships, determine directions, compare distances, extract information about more than one attributes at a location or the spatial distributions of one or two attributes. Some of these same questions were also intended to examine the effect of the various types of landform representation on the way spatial information was interpreted by students. Examples of these questions and tasks are:
Lake Marathon is located to the north, south, east or west of Spata?
Put a sign on the name of the town that has a railway and a highway passing through it.
Write down the name of two villages, which would go through when travelling on the highway from Thiva to Elefsina.
There were four more questions pertaining to landform in each questionnaire. Two were exactly the same in all the questionnaires whereas two others were slightly different. These questions directed students to compare heights or slopes, to determine decreasing or increasing elevation along a route, and to define in which hypsometric zone a place was located. Examples of these questions are:
Walking from Vilia to Mandra is the elevation decreasing, increasing or the same?
Which mountain has the steeper slope: Makron or Kithaironas?
Write the name of a village that is located on mountains.

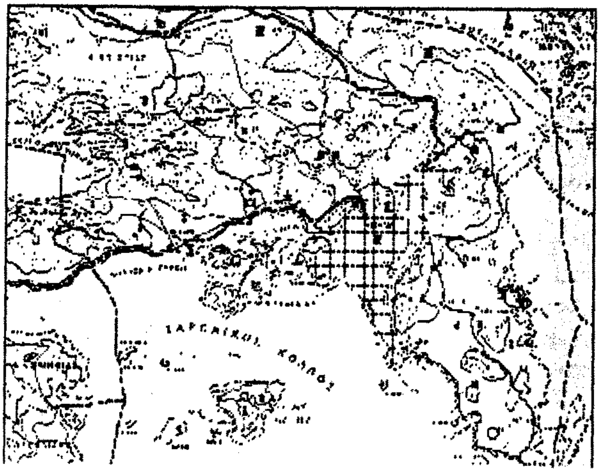

Fig. 1. Contour lines

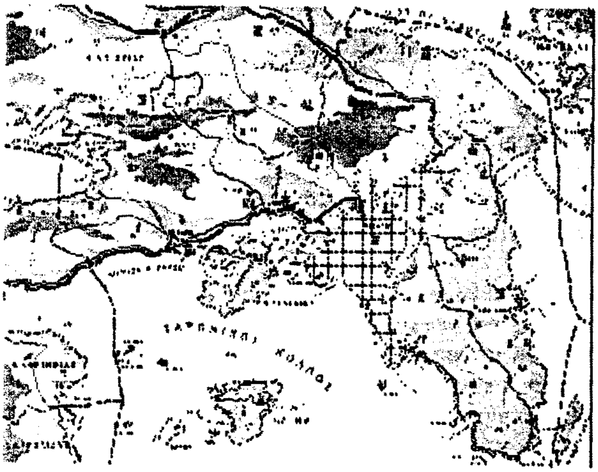

Fig. 2. Hypsometric tints

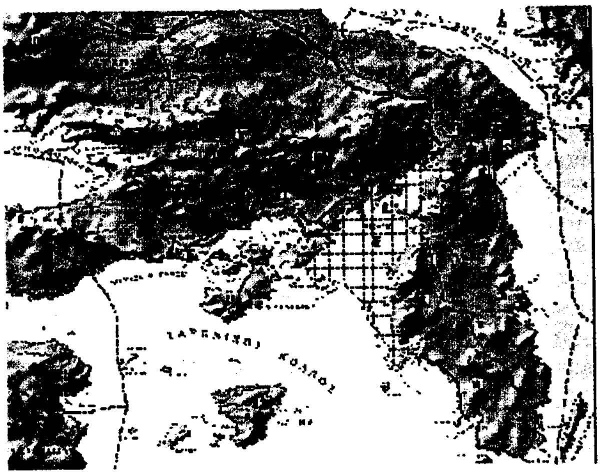

Fig. 3. Hill shading

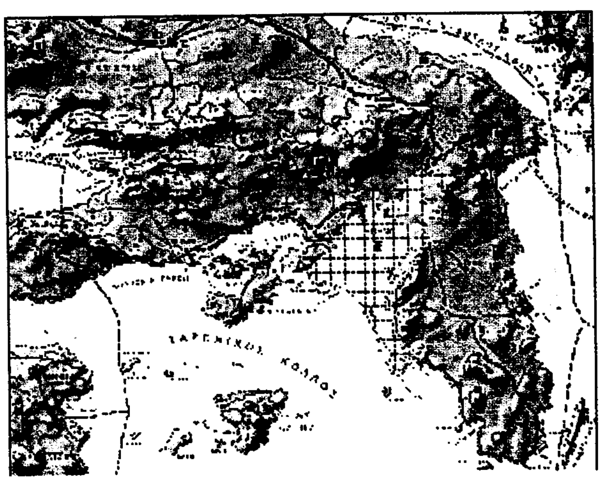

Fig. 4. Contour lines with hill shading

Sample description

Subjects of the test were students (718) in Grades 3 through 6 attending two primary schools in the Attiki Prefecture. More specifically, the students were from six Grade 3 classes (age eight), four Grade 4 classes (age nine), five classes of Grade 5 (age ten), and six Grade 6 classes (age eleven). For each class, the test took place in a forty-minute teaching period under standard classroom conditions. Approximately twenty-three students were tested at a time. Each of the test subjects received a map and a questionnaire. Children sitting close to one another received different types of maps. The distribution of the four types of maps for each grade is presented on Table 1. At the beginning of the test the purpose of the study was briefly explained. In addition students were given definitions and explanations on the landform representation methods, and directions on how to fill the questionnaire and to adhere the time available.

Table 1.

Sample composition

Age	(Map 1) Contour Lines	(Map 2) Hypsometric tints	(Map 3) Hill Shading	(Map 4) Shading + Contours	Total
8	44	41	36	47	168 (23%)
9	48	46	40	45	179 (25%)
10	41	41	41	43	166 (23%)
11	52	52	51	50	205 (29%)
Total	185 (26%)	180 (25%)	168 (23%)	185 (26%)	718 (100%)

STATISTICAL ANALYSIS - DISCUSSION

The percentage of correct responses given by the students for the eleven questions were used to calculate the mean number of scores for each age group. Group means and standard deviations are presented in Table 2. A one-way analysis of variance was performed which revealed a statistically significant effect for age group, $F(3,714) = 62.26$, $p<0.05$. A Sheffe multiple comparison test was performed. The results of the analysis indicated that all groups were significantly different from each other, ($p<0.05$). The only comparison that failed to reach significance was that between the groups of ten and eleven years old. Group mean-scores significantly increased from age eight to ten in extracting both planimetric and landform information (Table 2). Students aged ten and eleven reveal the same competence and this can be explained by the fact that these students work extenslively with lanfdorm maps in Geography from Grade 5.

Table 2.

Total scores by age group

Age	Planimetric	Landform	Mean
8	63 ± 20	40 ± 28	55 ± 18
9	72 ± 18	55 ± 28	66 ± 17
10	82 ± 18	63 ± 27	75 ± 17
11	82 ± 16	66 ± 25	76 ± 15
Mean	75 ± 20	56 ± 29	68 ± 19

The mean scores for each age group in extracting planimetric and landform information from the maps, (Table 2), were significantly different as indicated by paired t-tests at the 0.05 level. Students' performance in extracting planimetric information from maps was better than in extracting landform information. This finding applied to all four maps as shown in Table 3 which presents students mean scores in extracting the two kind of information from each map. This can be explained by the fact that to answer questions concerning the landform the map-reader needs to be able to conceive the terrain mentally, which is a difficult task for primary school students who have not developed abstract thinking.

Table 3.

Total scores by map type

Map	Planimetric	Landform	Mean
1	74 ± 21	50 ± 26	65 ± 20
2	76 ± 18	60 ± 29	70 ± 18
3	77 ± 19	66 ± 31	73 ± 19
4	74 ± 20	51 ± 26	66 ± 18
Mean	75 ± 20	56 ± 29	68 ± 19

Table 3 also reveals that the ability of children to extract planimetric information from maps was not influenced by the way the landform was presented. The same conclusion implied from an examination of the mean score of each question related to planimetric features separately. The relief of the area presented on maps was not very intense so its representation did not decrease the legibility of the other symbols portrayed.

After examining each question separately it turns out that some questions had very low scores compared to others. Specifically, there were the questions which directed students to determine the direction east west, (Table 4), and required students to perceive three attributes at a location (Table 5). These questions had very low scores when compared to mean scores of the planimetric questions (Table 3). Student's performance was better in determining the direction east west than north south (Table 4). For each map, paired t-tests indicated that the differences were significant at 0.05 level. Perceiving three attributes at a location is a difficult task for primary school students and supported the findings from a previous research study that examined the abilities of students to extract the spatial relations from maps of different scale [5].

Table 4.

Orientation scores

Map	East West	North South	Mean
1	47 ± 50	72 ± 45	60 ± 34
2	50 ± 50	78 ± 41	64 ± 33
3	55 ± 50	80 ± 40	68 ± 33
4	48 ± 50	78 ± 41	63 ± 32
Mean	50 ± 50	77 ± 42	64 ± 33

Table 5.

Distribution of 3 attributes

Map	L1(A1, A2, A3)
1	51 ± 50
2	47 ± 50
3	52 ± 40
4	49 ± 50
Mean	50 ± 50

The questions related to landform directed students to extract two types of spatial relations, one related to the interpretation of the landform and the other to the estimation of elevations. Mean scores of the questions related to landform interpretation are presented for each age group (Table 6) for each map (Table 7). A one-way analysis of variance revealed significant differences between the age groups' mean scores of questions related to landform interpretation, $F(3,714) = 12.51$, $p<0.05$. A Sheffe post hoc test revealed that the group of eleven years was significantly different from the groups of age eight and nine, and that the group of age ten was significantly different from the group of age eight, ($p<0.05$). The effect of map type to the same performance did not approach significance, $F(3,714) = 1.26$, $p = 0.3$. On the other hand, students' performance in comparing slopes on a map that portrayed the landform through hill shading was significantly higher than on maps with contour lines or contours and hill shading.

Table 6.

Landform interpretation by age group

Age	Variation	Slope	Mean
8	46 ± 50	46 ± 50	46 ± 41
9	55 ± 50	57 ± 50	56 ± 40
10	67 ± 47	66 ± 48	67 ± 38
11	68 ± 47	71 ± 45	69 ± 38
Mean	59 ± 49	60 ± 49	60 ±40

Table 7.

Landform interpretation by map type

Map	Variation	Slope	Mean
1	62 ± 49	53 ± 50	57 ± 37
2	60 ± 49		60 ± 49
3	57 ± 50	73 ± 45	65 ± 36
4	59 ± 50	57 ± 50	58 ± 36
Mean	59 ± 49	60 ± 49	60 ± 40

Mean scores for the questions related to estimation of elevations are presented in Table 8 by age group. A one-way analysis of variance revealed significant differences between the age groups' mean scores of questions related to elevation, $F(3,714) = 27.33$, $p<0.05$. A Sheffe post hoc test revealed that age groups of nine, ten and eleven were significantly different from age groups of eight, ($p<0.05$). The student's performance of the age of eight in determining elevations on maps was low. No significant progress occurred between nine to eleven years of age. t is interesting to remark that the mean score of all questions concerning the identification of landform from contour lines map was 50±26 (Table 3).

As stated in a previous research project [5] primary school students score better when extracting information presented by symbols varying in ordinal scale rather than in numerical scale. In the present test, when students were asked to find a village located between two specific contour lines they scored 17 ± 38. When they were asked to find a village in a specific hypsometric zone, they scored 53 ± 50 (Table 8).

Table 8.

Estimation of elevations by age group

Age	Elevation comparison	Elevation identification		Elevation distribution	Mean
		Numerical	Ordinal		
8	48 ± 50	12 ± 33	34 ± 48	34 ± 48	35 ± 33
9	68 ± 47	24 ± 43	54 ± 50	62 ± 49	54 ± 32
10	75 ± 44	19 ± 40	63 ± 49	76 ± 43	60 ± 33
11	81 ± 40	15 ± 36	58 ± 50	76 ± 43	62 ± 29
Mean	69 ± 46	17 ±38	53 ± 50	63 ± 48	53 ± 33

CONCLUSIONS

The present study has two aims. The first is to determine the age by which primary school student can be introduced to the different methods of landform representation. The second is to examine the effect of alternative landform representation methods on reading and interpreting the planimetric and hypsometric map content. Starting with the first aim it can be concluded that the crucial age of introducing children to landform representation is the age of nine (Table 2). Another conclusion is that children can be introduced to landform interpretation through hill shading representation (Tables 3 and 7). Further research is recommended on this subject. Concerning the second aim, the results of the statistical analysis show that reading and interpreting planimetric information is independent of the way landform is presented. The ability to extract planimetric information is increasing with ages (Table 2). The ability to extract hypsometric information also increases with age (Tables 6 and 8), but is also dependent on the method of landform representation (Table 7). More specifically, concerning the conception of landforms, landform interpretation is easier than the estimation of elevations (Tables 6 and 8). Correct slope estimation are significantly higher when hill shading representation is present (Table 7). Finally, the results of the present study show that primary school students, without having any knowledge of isarithmic mapping, are able to answer questions concerning contour lines representation after listening to our short definition (Table 3).

ACKNOWLEDGEMENTS

The assistance of Ms. M. Antonopoulou and Mr. Ch. Gitonas and the teachers of the two primary schools are gratefully acknowledged. We would also like to express our thanks to Ms. M. Kalogeraki and Ms. G. Papadaki, undergraduate students of our Department, for their efficient participation of the tests.

REFERENCES

[1] Boardman, D. (1989), "The development of graphicacy: children's understanding of maps", Geography, Vol. 74, No. 325.

[2] De Lucia, A. (1972), "The Effect of Shaded Relief on Map Information Accessibility", The Cartographic Journal, Vol. 9.

[3] Georgopoulos, A., Nakos, B., Mastoris, D., Skarlatos, D. (1997), "Three dimensional visualization of built environment using digital orthophotography", Photogrammetric Record, 15(90).

[4] Imhof, E. (1982), "Cartographic Relief Presentation", (ed.: Steward, H.J.), Walter de-Gruyter, New York.

[5] Michaelidou, E., Nakos, B., Filippakopoulou, B. (1997), A study on the ability of children in understanding the fundamental elements of reality presented on maps, in "Proceedings, 18th International Cartographic Conference", Vol. 2.

[6] Patton, J.C., Crawford, P.V. (1977), "The perception of Hypsometric Colours", The Cartographic Journal, Vol. 14.

[7] Phillips, R.J., De Lucia, A., Skelton, N. (1975), "Some Objective Tests of the Legibility of Relief Maps", The Cartographic Journal, Vol. 12.

[8] Piaget, J., Inhelder, B. (1967), "The child's conception of space", Routledge & Kegan Paul, London.

[9] Potash, L.M., Farrell, J.P., Jeffey, T. (1978), "A Technique for Assessing Map Releif Legibility", The Cartographic Journal, Vol. 15, No. 1.

[10] Robinson, A.H., Sale, R.D., Morrison, J.L., Muehrcke, Ph.C. (1985), "Elements of Cartography", (5th ed.), John Wiley & Sons, New York.

[11] Sandford, H.A. (1979), "Things Maps Don't Tell Us", Geography, Vol. 64, Part 4, No. 285.

[12] Tzelepis, N., Nakos, B. (1996), Evaluation study of hill shading methods, in "Proceedings, 2nd National Cartographic Conference", Hellenic Cartographic Society, Thessaloniki, Greece, (In Greek.)

[13] Wiegand, P., Stiell, B. (1997), "Children's Relief Maps of Model Landscapes", British Educational Research Journal, Vol. 23, No. 2.