The Ability of Elementary School Children to Analyse General Reference and Thematic Maps

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Abstract

Physical maps with hypsometric tints, political maps with a monochromatic background, large-scale maps for younger students, and small-scale maps for older students, as well as maps with a limited number of thematic layers, are the predominant map forms found in elementary school textbooks in both Greece and Cyprus. The ability of elementary school children between Grade 3 and Grade 6 to analyse map content on these types of maps is investigated in a series of tests. The variables considered are map scale, complexity of background, number of thematic layers, and representation of landforms. Results indicate the need for strategic use of different map forms in order to help students to develop the ability to analyse map content.

Keywords: children, cartography, map use, map analysis, spatial relationships

Résumé

Les cartes physiques aux teintes hypsométriques, les cartes politiques sur fond monochrome, les cartes à grande échelle destinées aux jeunes élèves et les cartes à petite échelle, aux élèves plus âgés, ainsi que les cartes ayant un nombre limité d'éléments thématiques sont les formes de cartes que l'on retrouve le plus fréquemment dans les manuels scolaires au niveau élémentaire en Grèce et à Chypre. Par le biais d'une série de tests, on étudie la capacité des enfants de l'élémentaire (3^{e} à 6^{e} année) à analyser le contenu cartographique de ces types de cartes. Les variables examinées sont l'échelle de la carte, la complexité du fond, le nombre d'éléments thématiques et la représentation des formes de relief. Les résultats révèlent qu'il faut utiliser stratégiquement les différentes formes de cartes afin d'aider les élèves à développer leur capacité à analyser le contenu d'une carte.

Mots clés : enfants, cartographie, utilisation des cartes, analyse des cartes, relations spatiales

Introduction

Maps are very powerful tools for spatial analysis, but unfortunately, in elementary education, both in Greece and in Cyprus, they are used mainly for recording things in place. Maps for students are usually simplified versions of maps for adults, limiting the potential for more advanced analysis by users. There is a need for maps in textbooks that can be used to address questions other than "What is this?" and "Where is that?" The need for maps that can support the development of children's ability to analyse geographic information has been widely recognized (Bausmith and Leinhardt 1998; Castner 1990). On the other hand, most research concerning the ability of elementary school children to use maps concentrates on symbol identification (Downs, Liben, and Draggs 1988) or symbol comprehension (Gerber 1984), as well as on the extraction of relationships that refer mainly to locations, for example, determining directions, measuring or comparing distances, and determining coordinates (Liben and Downs 1993; Miller 1982; Carswell 1971; Brown 1960). Little research has been conducted on how schoolchildren extract relationships that concern attributes at locations, for example, describing or comparing distributions (Heamon 1973). As a result, we do not have a complete view of the students' ability to analyse a map's content or of the influence of map forms on the development of this ability.

The present article documents a comprehensive study that examined the influence of the existing map forms used in elementary textbooks in both Greece and Cyprus on students' ability to analyse information. More specifically, the aim of the study was to examine the influence

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Table 1. The variation of the map forms used in the three tests

	"Scale and background complexity" test	**"Thematic layers" test**	**"Representation of landforms" test**
Scale	√	√	
Background complexity	√	√	
Number of thematic layers		√	
Representation of landforms			√

of map scale, background complexity, number of thematic layers, and methods of landform representation on the ability of students in Grades 3 to 6 (8 to 12 years old) to analyse map content. Three tests were conducted for the purposes of the study: the "Scale and background complexity test," which focuses on the influence of scale and background complexity of the maps; the "Thematic layers test," which focuses on the influence of scale, background complexity, and the number of thematic layers; and the "Representation of landforms test," which focuses on the influence of the methods of representation of landforms, as shown in Table 1.

Students in elementary Grades 3 through 6 are at the concrete stage of development, and, according to Jean Piaget and Bärbel Inhelder (1967), there are some limitations in their conception of space. Children's conception of space develops sequentially, from the simple topological relationships (e.g., proximity, order, separation, enclosure) to the more difficult conceptions of projective and Euclidean space (Piaget and Inhelder 1967). By the age of seven or eight, at the beginning of the concrete operational stage (7 or 8 to 11 or 12 years), children have already acquired most projective relationships and some Euclidean relationships. At this stage, they are capable of conservation (numerical), classification, ordering, and spatial reasoning tasks, but they cannot yet solve abstract problems. The age of nine, in the middle of the concrete operational stage, is considered a milestone in the development of spatial concepts and the projective and Euclidean systems. By the age of 11 or 12, when they have reached the formal stage, children develop an understanding of Euclidean space, which involves, among others, the notion of a real coordinate system (Piaget and Inhelder 1967). Subsequent psychological studies (e.g., Blades and Spencer 1989, 1994; DeLoache and Marzolf 1992; Bluestein and Acredolo 1979; Newcombe and Huttenlocher 1992; Presson 1982) have pointed out that the development of spatial abilities happens earlier than Piaget and Inhelder (1967) first suggested. Nevertheless, Piaget's work still influences mapping education in both Greece and Cyprus, and mapping activities start in Grade 3 (eight to nine years old) when, according to the above, children have acquired most of the projective relationships.

It is commonplace for mapping activities in elementary school to start with large-scale maps of the immediate environment, proceed with smaller scales of increasingly larger environments, and finally reach a very small scale in the world map. The map scale sets limits on the information that can be included and determines the amount of generalization to which the map is subjected. The smaller the scale, the more generalization is used on the map and the more abstract it becomes (Robinson and others 1995). On the other hand, large-scale maps retain a greater degree of iconicity, and, in addition, children are already familiar with most of the characteristics presented on large-scale maps, since they usually see them in their immediate environment. So it is not a coincidence that education mapping activities start with large-scale maps of the environment. But Karen Trifonoff (1995) found that Grade 2 students could identify symbols and describe spatial patterns from maps of different scales (neighbourhood, city, and national) equally well. Whether the scale influences the students' ability to analyse the information contained in the map is an issue in need of further study.

Physical and political maps are the most commonly used in Greek and Cypriot education. Political maps usually have a monochromatic background of a pale tint that does not convey any data, while physical maps have the conventional green-, yellow- and brown-tinted background that conveys data on land elevations. Jack Miller (1974) examined students in Grades 4 through 6 in extracting data concerning relationships among locations from a map with a light background colour and one with complex colour layers. Complex colour layers did not seriously distract Miller's study participants, who seemed quite able to disregard the colour arrays of the background and focus on what constituted the figures of the map. On the other hand, R.P. Kempf and G.K. Poock (1969) showed that tints may have a detrimental effect on the two-dimensional information of the map. In addition, Alan DeLucia's experimental results with adults "tend to indicate support for the notion that the use of shaded relief terrain symbology on a map to some degree impairs the ability of a map-reader to extract non-terrain information" (1972, 17). Whether the use of hypsometric tints in the background, in contrast to a monochromatic layer, influences students' ability to analyse the information of the map is an issue that requires further examination.

As has already been mentioned, in textbook maps the landform is usually depicted through hypsometric tints. Students learn to associate the colour green with plains, yellow with hills, and brown with mountains. According to Jeffrey Patton and Paul Crawford (1977), hypsometric maps using spectrally ordered colours accurately transmit data concerning topographic elevation, but also transmit inaccurate, unintended information relative to other physical geographic factors. Furthermore, Herbert Sandford (1979) warns that hypsometric colours may mislead the map user into visualizing a terraced landscape. Representation of landforms by means of contour lines may not transmit unintended and inaccurate information, but even students who have reached the formal stage appear to have difficulties in grasping the concept of contour lines (Boardman 1989). Patrick Wiegand and Bernadette Stiell, after examining children's relief maps of model landscapes, 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 the contours" (1997, 179). The effect of alternative methods of representing landforms in analysing planimetric and hypsometric map content by young students is another topic still open to research.

Maps in elementary textbooks are often simplified by portraying a limited number of layers. Whether the number of thematic layers affects children's ability to analyse the geographic information is an unanswered question. A child may be overwhelmed by a map with multiple layers and may not be able to focus on specific elements and extract specific information. From another point of view, if the number of layers is very limited, the map may become too abstract; as Henry Castner has pointed out, "we often provide children with maps that are visually simplistic but intellectually complex" (1990, 21). A very simplistic map may not activate map schemata to children; as Alan MacEachren writes, "appropriate cues must be present in a particular display before a map schema is selected by the child as the appropriate vehicle for understanding" (1995, 196). In addition, a map with very limited layers of information does not promote the student's understanding of the interconnections between different features, and analysis is confined to "what is" and "where is" questions.

Joel Morrison (1976) considers map analysis as a level of processing that follows map reading and precedes map interpretation. Castner (1990) explains that map analysis is essentially systematic map reading, involving a sequence of map-reading tasks and aiming at some specific goal, such as distance measurement or finding the best route. As a result, map users gain a certain familiarity with both the image and the place (the information presented) so that they are able to talk about them and describe them to others. In this study, the ability of students to analyse information in maps of different forms is examined through their performance in extracting four types of relationships defined by Arthur Robinson and others (1995):

- relationships among locations, R1: (L1 - L2)
- relationships among various attributes at one location, R2: L1(A1, A2, A3)
- relationships among the locations of the attributes of a given distribution or spatial distribution of an attribute, R3: (L1)A1 - (L2)A1
- relationships among the locations of derived or combined attributes of given distributions or spatial distribution of two attributes, R4: L1(A1, A2) - L2(A1, A2)

Methodology

The "Scale and background complexity" test, the "Thematic layers" test, and the "Representation of landforms" test were designed to meet the multiple objectives of the study. For each test, maps were designed and corresponding questionnaires were composed. The content of the questionnaires for the three tests is given in Appendices A, B, and C respectively. Areas familiar to the participants were depicted on the maps so that time would not be lost on interpreting the geographical space as a whole. The questions were intended to evaluate the children's ability to extract relationships of the types defined above – for example, to define topological relationships, determine directions, compare distances, and extract information about more than one attribute at a location or the spatial distributions of one or two attributes. Not all the maps depicted information that could support the extraction of all four types of spatial relationships, so the content of the corresponding questionnaires had to be adapted and the appropriate questions included. The questionnaires used a format and vocabulary appropriate to elementary school students. The format was based on samples provided to teachers by the Ministry of Education and Culture of Cyprus (Aspros and Efthimiou 1995) for evaluating students' competence in geography courses. Questions demanding one-word answers and multiple-choice questions were included. Suggestions of an elementary school teacher in Cyprus were taken into account so that the vocabulary of the questionnaires would be familiar even to Grade 3 students.

In the "Scale and background complexity" test, three general reference maps were used, with corresponding questionnaires that were completed by all participants. For the "Thematic layers" test, 10 general reference and thematic maps were used. A questionnaire could correspond to more than one map. Each participant had to fill out two questionnaires corresponding to different maps. For the "Representation of landforms" test, four general reference maps and corresponding questionnaires were used. Each participant had to complete one questionnaire corresponding to a map.

The participants were drawn from Grade 3 (8–9 years), Grade 4 (9–10 years), Grade 5 (10–11 years), and Grade 6 (11–12 years) classes at elementary schools in Limassol, Cyprus, and Athens, Greece. In both Cyprus

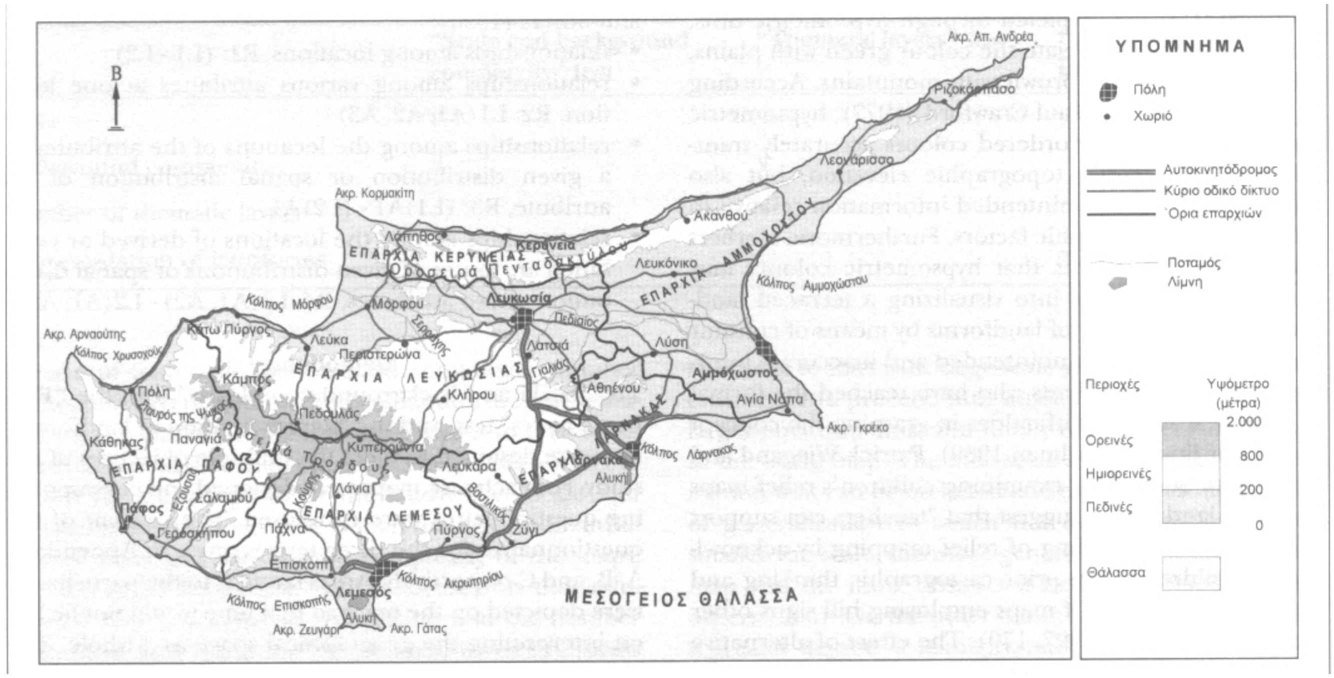

Figure 1. Physical map of Cyprus

and Greece, elementary school attendance is compulsory and lasts six years, from the age of six (Grade 1) to the age of 11–12 (Grade 6). In Cyprus, mapping activities start in Grade 3 with large-scale maps of the familiar environment (class and school neighbourhood) and small-scale maps of the country. The emphasis is given on the identification of symbols. In Grade 4 students analyse information on large-scale maps of towns and small-scale physical, political, and thematic maps of Cyprus and Greece. In Grades 5 and 6 small-scale physical, political, and thematic maps of different countries and continents are used. The mapping experience of Greek students is very similar, but with emphasis on the map of Greece.

The participating classes were selected randomly. All students in a class completed in the same test; none took more than one test. During the test the students sat in their usual places in the classroom. Students sitting together did not fill out the same questionnaires simultaneously. The duration of the tests did not exceed 40 minutes. At the beginning of the test the investigator explained the purpose of the study to the participants, and directions were given on completing the questionnaires and adhering to the time available. The teacher remained in the classroom during the tests but did not interfere.

Description of the "Scale and Background Complexity" Test

The "Scale and background complexity" test aimed to examine the influence of scale and background complexity on students' ability to analyse map information. For the purposes of the test, three coloured maps were designed similar to those typically found in textbooks, and three questionnaires were composed. The maps are

- *A physical map of Cyprus (scale 1:1,000,000).* Hypsometric zones are portrayed using conventional colours (green, yellow, brown). Area symbols are used for towns, a black dot point symbol for villages, a double red line for highways, a single red line for secondary roads, and a black line for district boundaries. Rivers, lakes, and the sea are blue in colour. (See Figure 1.)
- *A political map of Cyprus (scale 1:1,000,000)* that includes all the information of the previous map except the hypsometric zones.
- *A map of a part of Limassol (scale 1:4000)* that displays buildings, building blocks and plots, green areas, roads, pedestrian zones, rivers, fountains, and water features. Pictorial point symbols are used to represent different buildings and places such as schools, museums, and tennis courts. Two lines, one red and one blue, were drawn to indicate two routes. (See Figure 2a.)

The questionnaires included a total of 23 questions (nine relating to the physical map, nine to the Limassol map, and five to the political map) that required the extraction of three types of relationships, as described above. All the questions are presented in Appendix A; for each question the relevant map is given in parentheses. The answers to the multiple-choice questions are given in italics. Five questions that referred to the physical

Table 2. Samples of the first and second type of questions in the "Scale and background complexity" test

R1 (L1 - L2):	Put "√" in the correct statement: Nicosia is located to the *north / south / east / west* of Famagusta Put "√" in the correct statement: The museum is located to the *north / south / east / west* of the court.
R2 L1(A1, A2, A3):	Write the name of a village that lies in the hills of the Nicosia district and has a river passing through it. Draw a circle around the part of the footpath that is located next to a river and a fountain.

Table 3. Participants in the "Scale and background complexity" test

		Grade				
	Sex	**3**	**4**	**5**	**6**	**Total**
School A (Limassol)	Boys	31	28	34	27	120
School B (Limassol)		24	32	33	27	116
Total (Boys)		55	60	67	54	236
School A (Limassol)	Girls	29	22	24	27	102
School B (Limassol)		22	24	28	25	99
Total (Girls)		51	46	52	52	201
Total		106	106	119	106	437

and political maps had the same formulation but different objects and required the identification of symbols and the extraction of relationships among locations: counting characteristics, determining the topological relationship of vicinity, determining direction, and comparing routes. The same relationships had to be extracted from the map of Limassol. There was correspondence between six of the questions, which referred to both the physical map and the map of Limassol. In addition to symbol identification and relationships among locations, as mentioned above, the relationships among various attributes at locations also had to be extracted from both maps. Lines indicated the routes that had to be compared on a large-scale map. Three questions that referred to the map of Limassol focused on localizing specific features presented with pictorial point symbols, determining a route between them, and determining a feature at a specific address, tasks often executed on large-scale maps. Three more questions that referred to the physical map focused on extracting information concerning landform, which is the basic feature of the map, and asked participants to locate a village on the plain, in the hills or in the mountains; to locate a village in three different hypsometric zones with specific elevations; and to define the change in elevation along a route. Examples of the questions relevant to the physical or political map and to the Limassol map are given in Table 2.

For this test, classes of Grades 3 to 6 were randomly selected from two elementary schools (two classes per grade per school, for a total of 16 classes), one located in the city centre (School A) and the other in a suburb of Limassol, Potamos Germasogeias (School B). The total sample consisted of 437 students: 106 from Grade 3, 106 from Grade 4, 119 from Grade 5, and 106 from Grade 6 (Table 3). All participants had to fill in three questionnaires. Half received the physical map first, the map of Limassol second, and the political map last; the other half received them in reverse order.

Results of the "Scale and Background Complexity" Test

The percentages of correct responses for each question are given in Tables D1, D2, and D3 in Appendix D for the physical map, the political map, and the map of Limassol respectively. A Mann-Whitney test showed no statistically significant difference between the mean scores of the students from the two different schools on the whole test ($z = -0.518$, $p > 0.05$) or between the mean scores for boys and girls ($z = -0.240$, $p > 0.05$). In order to compare students' performance on the small-scale physical map of Cyprus and the large-scale map of Limassol, the correct responses for the six corresponding questions included in each questionnaire were analysed. For each grade, the total sample, the mean score (M), and the standard deviation (SD) are presented in Table 4. A Wilcoxon rank test of two related samples was performed to detect the presence of significant differences ($p < 0.05$) between the mean scores of students on the two maps (Table 4). For Grade 3, the mean score for the large-scale map is significantly higher ($p < 0.05$) than the mean score for the small-scale map. For Grade 5, on the other hand, the mean score on the small-scale map is significantly higher ($p < 0.05$) than for the large-scale map. Map scale did not have any effect on the mean scores of Grade 4 and 6 students. Grade 3 students, who had limited experience with maps of both scales, showed more in-

Table 4. Percentage of correct responses for small-scale and large-scale maps on the "Scale and background complexity" test

	Small-scale map		Large-scale map		Wilcoxon test	
Grade	***M***	***SD***	***M***	***SD***	***z***	***p***
3	44	20	50	22	–2.485	<0.05
4	58	24	58	24	–0.036	>0.05
5	65	25	59	20	–2.596	<0.05
6	77	18	76	24	–0.288	>0.05
Total	61	25	60	24	–0.436	>0.05

M = mean, *SD* = standard deviation

Table 5. Percentage of correct responses for the physical and political maps on the "Scale and background complexity" test

	Physical map		Political map		Wilcoxon test	
Grade	***M***	***SD***	***M***	***SD***	***z***	***p***
3	45	20	58	22	–4.566	<0.05
4	62	24	72	24	–3.728	<0.05
5	66	25	80	20	–5.121	<0.05
6	80	18	89	24	–4.216	<0.05
Total	64	25	75	24	–8.770	<0.05

M = mean, *SD* = standard deviation

terest in the large-scale map during the test. In the curriculum for Grade 4, mapping activities cover both scales, with emphasis on small-scale maps, while the other two grades are limited to small-scale maps. As a result, there was no improvement in performance on the large-scale map between Grade 4 and Grade 5, as revealed by the results of the Mann-Whitney test ($z = -2.00$, $p > 0.05$), but Grade 5 students were able to analyse the small-scale map better than the large-scale map.

Based on a more analytical examination of the responses, the results show that the competence of students in each grade to extract specific relationships was not the same for the large- and small-scale maps. Their performance in counting characteristics included in a district was significantly superior when they used the small-scale map; on the other hand, their performance in determining a direction was significantly inferior on the same map. But this may be attributable to the relative position of the features, which was on the east–west axis on the small-scale map but on the north-south axis on the large-scale map. The issue was examined more analytically in the "Thematic layers" test. Students in all grades had no problems in identifying symbols on maps at both scales. The students' performance in comparing the length of routes did not differ significantly between the two scales. The two lines drawn on the roads, which were represented on the map by area symbols to indicate the routes, facilitated the comparison of routes on the large-scale map. As the results indicate, students in all grades could locate the two features represented by pictorial point symbols on the large-scale map, but they had difficulty in drawing a route between them. So it is possible that if lines on the large-scale map had not indicated the routes, students might have had problems in comparing them. Even for Grade 6, only slightly more than half the students (54%) managed to locate a building next to a green area at a specific address, indicating that they had difficulty with tasks that are very often executed using large-scale maps.

The percentage of correct responses for the five questions dealing with physical and political maps of Cyprus was used to calculate the mean score for each grade and the total sample for extracting spatial relationships (Table 5). The Wilcoxon test of two related samples was performed to detect the presence of significant differences ($p < 0.05$) between students' mean scores on the two maps for each grade (Table 5). Students in each grade performed significantly better in extracting spatial relationships from the political map (with simple monochromatic background) than in extracting such relationships from the physical map, with its more complex background. This difference was obtained for each relationship. These results contradict the findings of Miller (1974, 1982), who states that fourth-, fifth-, and sixth-grade students were not seriously distracted by the complex colour layers of a physical map and were able to look through and disregard colour array. In contrast, our results show that the depiction of hypsometric tints on the background impaired, to a certain degree, students' ability to extract information. Our results are in accordance with those of DeLucia (1972) and Kempf and Poock (1969), who found that the use of shaded relief terrain symbology or tints seems to impede adult readers' efforts to extract two-dimensional information.

In terms of extracting information for the third dimension and, more specifically, information about landform representation from a physical map, it appears that almost half of Grade 3 students were able to locate a village in the plain, hill, and mountain zones and define the change of elevation (45% and 51% respectively). However, only half of the Grade 6 students (52%) managed to locate villages at specific hypsometric zones, which were indicated by their elevations. These results show that extracting information about landform representation was significantly more difficult when the information was perceived on a numerical scale rather than on an ordinal scale.

Description of the "Thematic Layers" Test

The "Thematic layers" test examined the effects of the number of thematic layers on students' ability to analyse map content. For the purposes of the study, four series of maps – a total of 10 coloured maps – were designed and

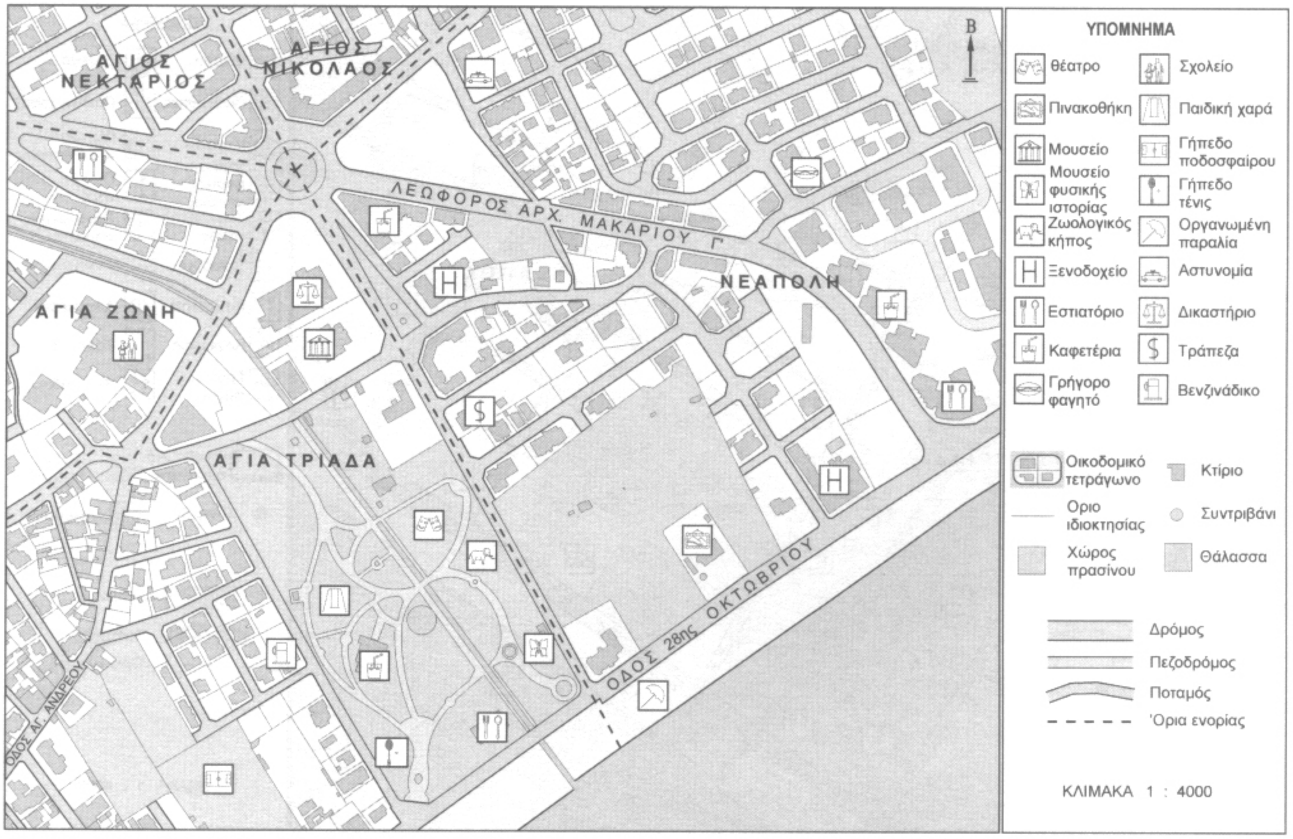

Figure 2a. The three maps of a part of Limassol used in the study: (a) map of all layers (Lim1)

corresponding questionnaires composed. The maps were similar to typical textbook maps. The series of maps were as follows:

- *Physical maps of Cyprus (scale 1:1,000,000).* The first map in the series (Ph1) is the one used in the "Scale and background complexity" test (Figure 1). The second (Ph2) was produced by omitting the layers of highway and secondary roads, while the third (Ph3) was produced by further omitting the layers of rivers and district boundaries.
- *Political maps of Cyprus (scale 1:1,000,000).* The first map in the series (Pol1) is the one used in the "Scale and background complexity" test. The second (Pol2) was produced by deleting the layers of highways, secondary roads, and district boundaries.
- *Population maps of Cyprus (scale 1:1,000,000).* In the first map (Pop1) in this series, graded red circles portray the populations of towns and villages. Hypsometric zones are depicted by different values of yellow and district boundaries by a black line symbol. The second map (Pop2) was produced by deleting the layers of hypsometric zones and district boundaries.
- *Maps of a part of Limassol (scale 1:4000).* The first map in the series (Lim1) is the one used in the "Scale and background complexity" test (Figure 2a). The second map (Lim2) was produced by omitting the buildings, plots, and pedestrian zones (Figure 2b). The third map (Lim3) was produced by further omitting the layers of green areas and township boundaries (Figure 2c).

Using the maps from the previous test ("Scale and background complexity") enabled a comparison of the results of the two tests. For the first map of each series, a questionnaire was composed with questions requiring the extraction of different types of spatial relationships (eight questions for the physical map, four for the political map, five for the population map of Cyprus, and eight for the map of Limassol). For the rest of the maps the questionnaires had to be adapted to map content by omitting questions. All the questions are given in Appendix B; for each question the relevant maps are noted in parentheses. Four questions regarding the physical and political maps and the maps of Limassol concerned relationships among locations: determining the topological relationship of vicinity, comparing routes, determining direction on the north–south axis, and determining direction on the east–west axis. These four questions were the same for the physical and political maps. Four more questions regarding the physical map and the map of Limassol dealt with the relationships among two and

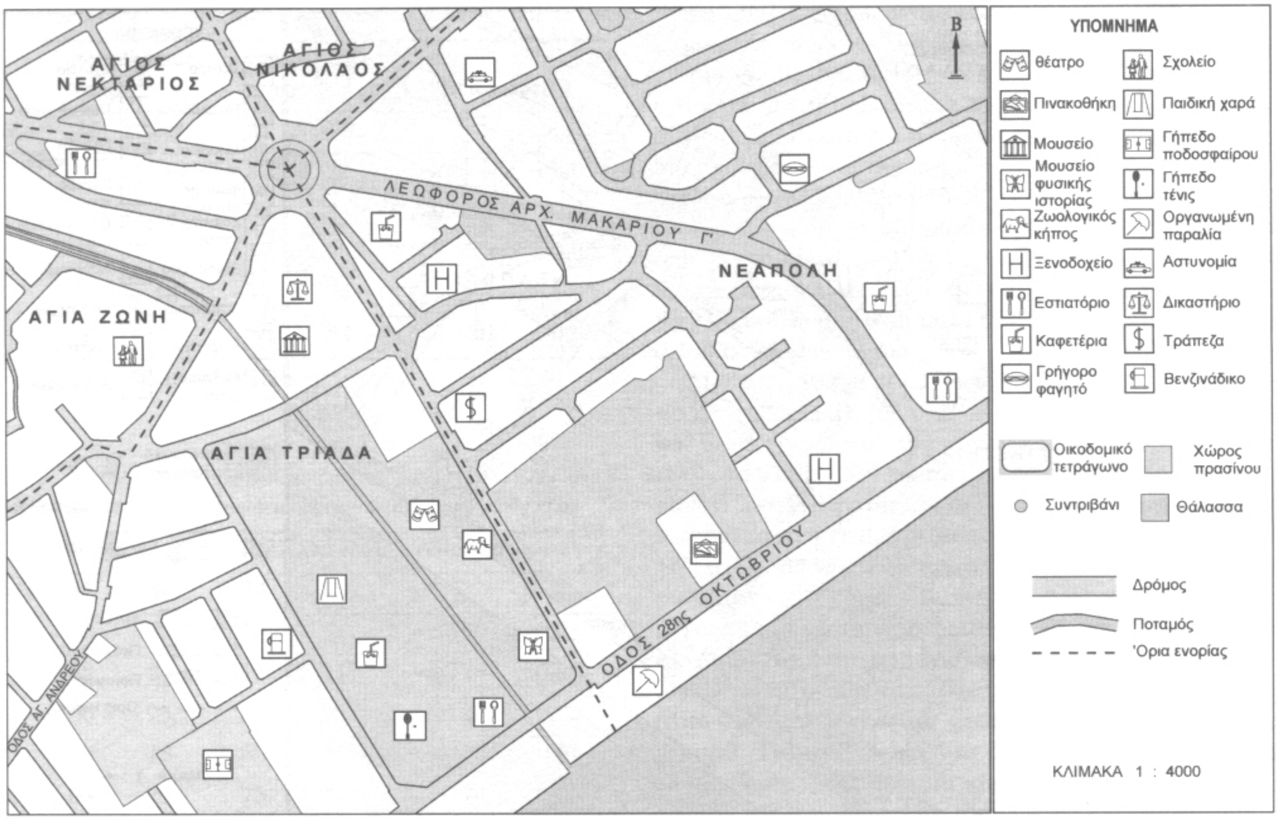

Figure 2b. The three maps of a part of Limassol used in the study: (b) map omitting three layers (buildings, plots, and pedestrian zones) (Lim2)

Table 6. Samples of the third and fourth types of questions in the "Thematic layers" test

R3 (L1) A1 - (L2) A1:	Write the name of a village that lies (a) in the plain (b) on the hill (c) on the mountain. Put "√" in the correct statement: Walking in 28th Octovriou street I come across *a bank and an art gallery / an art gallery and a hotel / a hotel and a school / a café and a museum*
R4 (L1) A1 A2 - (L2) A1 A2:	Put "√" in the correct statement: The settlements (towns and villages) that have the largest population are located on *plains / hills / mountains.* Put "√" in the correct statement: *The bank is located at a smaller building block than the fast food / The petrol station is located at a smaller building block than the bank / The petrol station is located at larger building block than the fast food.*

three attributes at a location and the spatial distribution of one and two attributes. There was correspondence between seven questions regarding the physical map and the map of Limassol concerning the spatial relationships dealt with. The eighth question pertaining to the physical maps concerned the extraction of numeric information from hypsometric zones, whereas the eighth question relative to the maps of Limassol concerned the distribution of two attributes. The questions regarding the thematic maps of population required the extraction of two types of relationships: spatial distribution of one and two attributes.

Examples of questions demanding the extraction of the first and second types of spatial relationships defined by Robinson and others (1995) are given in Table 2. Examples of questions of the third type, which related to the physical maps and the maps of Limassol, as well as questions of the fourth type, which related to the population maps and the maps of Limassol, are given in Table 6.

The sample for this test consisted of 1118 students in

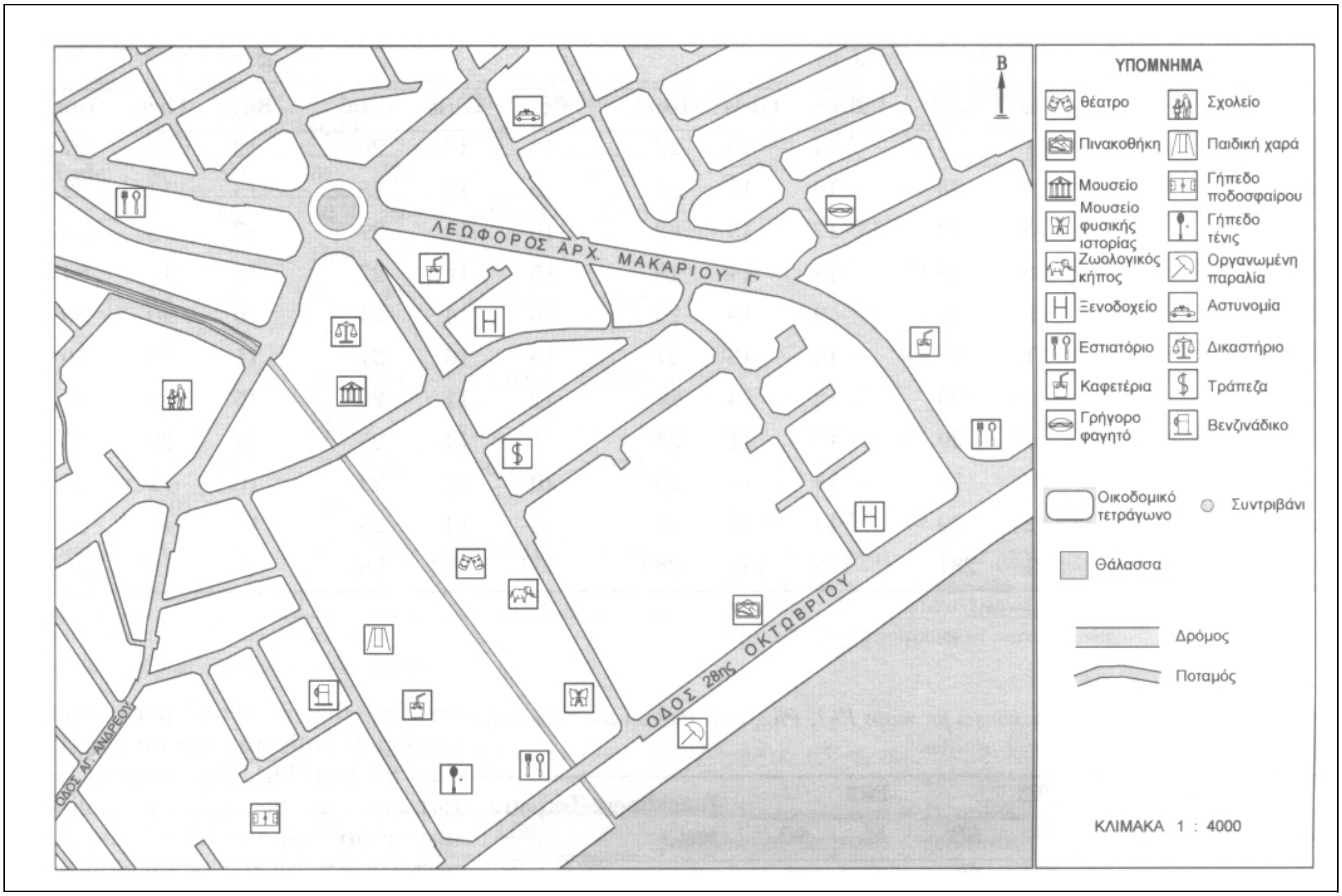

Figure 2c. The three maps of a part of Limassol used in the study: (c) map omitting two more layers (green areas and township boundaries) (Lim3)

Grades 3 (281), 4 (280), 5 (264), and 6 (293) from 10 elementary schools (Schools C through L) in Limassol (see Table 7). The schools were selected using systematic sampling (Markidis 1997): The 40 elementary schools of Limassol and its suburbs were listed in ascending alphabetical order; using the randomly selected number four, every fourth school on the list was selected to participate. From each school, a class from each grade was selected randomly. All students in the selected classes participated in the test. Each participant received a pair of maps and filled out the corresponding questionnaires. Five pairs of maps were defined (Ph1/Pop2, Ph2/Pop1, Ph3/Lim2, Pol1/Lim3, Pol2/Lim1); two classes from each grade, selected randomly, received each pair of maps.

Results of the "Thematic Layers" Test

Appendix D gives the percentages of correct responses for each question in Tables D4 (physical maps), D5 (political maps), D6 (population maps), and D7 (maps of Limassol). The number of participants is given in parentheses for each question. Prior to analysis of students' performance on the test, the homogeneity of the groups was examined by testing the ability of groups that received different maps to extract the same spatial relationships. This initial examination was considered necessary in case there was a significant difference in performance on different maps in a series, in which case the difference would not be attributed to differences in the groups' capabilities. The examination of homogeneity of the groups was based on their performance on a question included in all the questionnaires (for physical maps, question 30; for political maps, question 25; for population maps, question 34; for maps of Limassol, question 44; see Appendix B). The "Scale and background complexity" test revealed that this question was of moderate difficulty. Assuming homogeneity across all groups, the statistical analysis was then carried out. For each series, the mean scores and the standard deviations, derived from the percentage of correct responses on the common questions relative to the maps in a series, are presented in Tables 8–11. The results of a Jonckheere-Terpstra test (for several independent samples) or the Mann-Whitney test (for two independent samples), which were applied to compare groups' performance on different maps, are also given in these tables, as well as the number of participants in parentheses. The Mann-Whitney test did not reveal any significant difference ($p > 0.05$) between boys' and girls' performances in ex-

Table 7. Participants in the "Thematic layers" test

Grades	3			4			5			6		
Sex	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total
School C*	18	11	29	14	13	27	13	13	26	12	15	27
School D	19	14	33	16	12	28	16	12	28	15	17	32
School E	18	15	33	17	15	32	15	14	29	17	13	30
School F	17	6	23	14	14	28	15	12	27	13	11	24
School G	17	13	30	9	19	28	10	14	24	10	20	30
School H	11	11	22	14	13	27	15	16	31	11	19	30
School I	12	11	23	12	14	26	12	11	23	15	16	31
School J	20	9	29	13	11	24	11	14	25	14	20	34
School K	11	19	30	15	14	29	10	13	23	16	12	28
School L	17	12	29	14	17	31	14	14	28	13	14	27
Total	160	121	281	138	142	280	131	133	264	136	157	293

*Schools C–L are located in Limassol.

Table 8. Percentage of correct responses for maps Ph1, Ph2, and Ph3 on the "Thematic layers" test

Grade	Ph1 *M*	Ph1 *SD*	Ph2 *M*	Ph2 *SD*	Ph3 *M*	Ph3 *SD*	Jonckheere-Terpstra test	
3	32 (55)	23	29 (59)	23	31 (56)	23	–0.082	$p > 0.05$
4	41 (54)	21	43 (57)	25	56 (58)	26	3.118	$p < 0.05$
5	56 (53)	31	63 (52)	25	57 (49)	22	–0.150	$p > 0.05$
6	66 (58)	24	63 (61)	24	70 (55)	24	0.821	$p > 0.05$
Total	48 (220)	28	49 (229)	28	53 (218)	28	2.073	$p < 0.05$

M = mean, *SD* = standard deviation
Number of participants in parentheses

tracting spatial relationships from each map series.

Table 8 presents students' performance on the series of physical maps. The Jonckheere-Terpstra test revealed a statistically significant difference ($p < 0.05$) between Grade 4 students and the total sample in terms of performance on physical maps with a different number of thematic layers. Furthermore, the Mann-Whitney test revealed that the performance of Grade 4 students on the physical map Ph3, which had the fewest layers, was significantly better ($p < 0.05$) than their performance on physical maps Ph1 and Ph2. Analysis of the total sample revealed that students' performance was significantly superior for map Ph3 than for map Ph1. The students' performance on the series of political maps is presented in Table 9 and their performance on the population map series in Table 10. Among Grade 5 students the performance differed significantly ($p < 0.05$) for both the political map and the population map depicting all thematic layers (Pol1, Pop1) versus the maps with the smallest number of layers (Pol2, Pop2), as determined by the Mann-Whitney test. Students' performance on the series of Limassol maps is presented in Table 11. The performance of Grade 6 students, as well as the performance of the entire sample, for the map portraying all the thematic layers (Lim1) was significantly better ($p < 0.05$) than for the rest of the maps (Lim2, Lim3), which portrayed fewer layers.

The manner in which the number of thematic layers affected the analysis of maps by these elementary school children, therefore, is not a straightforward issue. It must be examined in the context of other parameters, such as scale, background complexity, and the experience of the map user. Results for small-scale maps indicate that the number of thematic layers did not have a significant effect on the performance of students in Grade 3 or Grade 6. This makes sense, given the Grade 3 students' limited experience with small-scale maps and their low performance in extracting spatial relationships from those maps, and given the considerable experience of Grade 6 students with small-scale maps

Table 9. Percentage of correct responses for maps Pol1 and Pol2 on the "Thematic layers" test

	Pol1		Pol2		Mann-Whitney test	
Grade	***M***	***SD***	***M***	***SD***	***z***	***p***
3	33 (52)	26	40 (59)	29	–1.129	>0.05
4	58 (56)	24	61 (55)	27	–1.018	>0.05
5	74 (55)	21	54 (55)	26	–3.944	<0.05
6	77 (59)	30	75 (60)	26	–0.791	>0.05
Total	61 (222)	22	58 (229)	30	–1.340	>0.05

M = mean, *SD* = standard deviation
Number of participants in parentheses

Table 10. Percentage of correct responses for maps Pop1 and Pop2 on the "Thematic layers" test

	Pop1		Pop2		Mann-Whitney	
Grade	***M***	***SD***	***M***	***SD***	***z***	***p***
3	45 (59)	26	53 (55)	34	—1.601	>0.05
4	58 (57)	29	64 (54)	31	–1.324	>0.05
5	77 (52)	22	64 (53)	30	–2.239	<0.05
6	78 (61)	22	75 (58)	24	–0.494	>0.05
Total	64 (229)	29	64 (220)	30	–0.335	>0.05

M = mean, *SD* = standard deviation
Number of participants in parentheses

Table 11. Percentage of correct responses for maps Lim1, Lim2, and Lim3 on the "Thematic layers" test

	Lim1		Lim2		Lim3		Jonckheere-Terpstra test	
Grade	***M***	***SD***	***M***	***SD***	***M***	***SD***		
3	39 (59)	28	30 (56)	20	42 (52)	22	0.973	*p* > 0.05
4	47 (55)	21	46 (58)	24	45 (56)	26	–0.769	*p* > 0.05
5	54 (55)	23	54 (49)	25	50 (55)	26	–0.549	*p* > 0.05
6	76 (60)	24	63 (55)	24	56 (59)	22	–4.745	*p* < 0.05
Total	55 (229)	28	48 (218)	26	49 (222)	25	–2.434	*p* < 0.05

M = mean, *SD* = standard deviation
Number of participants in parentheses

and their much higher performance in extracting spatial relationships from such maps. In school, students are introduced systematically to map analysis in Grade 4, mainly with small-scale maps. In this grade the limited number of thematic layers of a physical map, with the vivid colours on the rather complex background, helped students to extract spatial relationships. On the other hand, the elimination of thematic layers from small-scale maps with simple, pale backgrounds (such as the political and the population maps used for the test), or from large-scale maps, resulted in very simplistic representations, which had a negative influence on the performance of older students (Grades 5 and 6) in extracting spatial relationships.

The "Thematic layers" test enabled us to again compare students' performance on the small-scale physical map and on the large-scale map of Limassol (see Table 12). The comparison was based on students' performance on seven questions relating to physical maps Ph1 and Ph2 and to Limassol maps Lim1 and Lim2. For Grades 4 through 6 and for the total sample, students' performance in extracting spatial relationships was higher on the small-scale map. Application of the Mann-Whitney test revealed significantly ($p < 0.05$) superior performance on the small-scale map for Grade 5 and for the total sample. The results for Grade 5, but not the results for Grade 3, confirm those of the "Scale and background complexity" test.

The "Thematic layers" test also offered another opportunity to compare students' performance on maps with different levels of background complexity, such as the physical and political maps of Cyprus (see Table 13). The comparison was based on the students' performance on four questions related to the physical maps Ph1 and Ph2 and the political map Pol1. For Grades 4 through 6 and for the total sample, performance in extracting spatial relationships was higher for the political map. The Mann-Whitney test revealed significantly higher performance ($p < 0.05$) for Grade 4, Grade 6, and the total sample. The results for Grades 4 through 6 confirmed those of

Table 12. Percentage of correct responses on the small-scale and large-scale maps of the "Thematic layers" test

	Small-scale map		Large-scale map		Mann-Whitney test	
Grade	***M***	***SD***	***M***	***SD***	***z***	***p***
3	42 (114)	24	41 (115)	23	–0.627	>0.05
4	52 (111)	22	49 (113)	20	–1.191	>0.05
5	71 (105)	23	59 (104)	22	–3.996	<0.05
6	74 (119)	20	72 (115)	22	–0.298	>0.05
Total	59 (449)	26	56 (447)	25	–2.078	<0.05

M = mean, *SD* = standard deviation
Number of participants in parentheses

Table 13. Percentage of correct responses on the physical and political maps of the "Thematic layers" test

	Physical map		Political map		Mann-Whitney test	
Grade	***M***	***SD***	***M***	***SD***	***z***	***p***
3	43 (114)	26	42 (52)	25	–0.930	>0.05
4	51 (111)	20	63 (56)	23	–3.525	<0.05
5	69 (105)	24	73 (55)	20	–1.837	>0.05
6	72 (119)	23	80 (59)	24	–2.216	<0.05
Total	58 (449)	26	66 (222)	27	–3.932	<0.05

M = mean, *SD* = standard deviation
Number of participants in parentheses

the "Scale and background complexity" test.

Further analytical examination of the students' performance revealed that extracting specific relationships among locations was more difficult for some students on a large-scale map, whereas others experienced greater difficulty when using a small-scale map. Students in all grades had significantly weaker performances in comparing routes on large-scale maps than on small-scale maps, confirming the results of the "Scale and background complexity" test. They also had greater difficulty in determining direction on the north–south axis, but significantly superior performance with both physical and political maps in determining the direction on the east–west axis, on large-scale as opposed to small-scale maps. On small-scale physical and political maps, determining direction on the east–west axis was significantly more difficult than determining direction on the north–south axis, confirming the findings of other researchers (Tversky 1981). However, no such difference was evident for large-scale maps. The vast majority of Grade 3 students were able to extract the topological relationship of vicinity from both large-scale and small-scale maps.

Another easy task, even for Grade 3 students, was to compare the populations of two towns depicted as graduated point symbols (circles) on the population map. Half of the Grade 3 students managed to order four graduated point symbols according to the relative population they represent. Nevertheless, even Grade 6 students experienced difficulty in extracting numerical information from graduated point symbols: only half of them managed to estimate the magnitude of population represented by graduated point symbols.

Concerning the extraction of relationships that refer to attributes, the entire test proved that, on both small- and large-scale maps, relationships among three attributes at one location and relationships of the spatial distribution of two attributes were more difficult for children to extract than relationships between two attributes at a location or the spatial distribution of one attribute. The difficulty of extracting relationships increased when the attributes were in numerical scale. Confirming the results of the "Scale and background complexity" test, the "Thematic layers" test made it clear that participants had difficulty in extracting information related to landforms from both physical and population maps when the hypsometric zones were determined by elevations.

Description of the "Representation of Landforms" Test

The purpose of the "Representation of landforms" test was to examine the effect of alternative methods of landform representation on the analysis of planimetric and hypsometric map content. Four coloured general maps of the Attiki prefecture at a scale of 1:500,000 were designed. Each map combined three layers of information:

- *Landform information* was portrayed using four different methods: contour lines (Cnt) (Figure 3a), a combination of hill shading and contour lines (Sh/Cnt) (Figure 3b), hypsometric tints (HT) (Figure 3c), and hill shading (Sh) (Figure 3d).
- *Planimetric information* was portrayed in the same way on all maps and included features such as boundaries, roads, towns, villages, and rivers.
- *Lettering of places and features* was identical for all maps.

Four questionnaires of 11 questions each were created, one for each of the different landform maps. Appen-

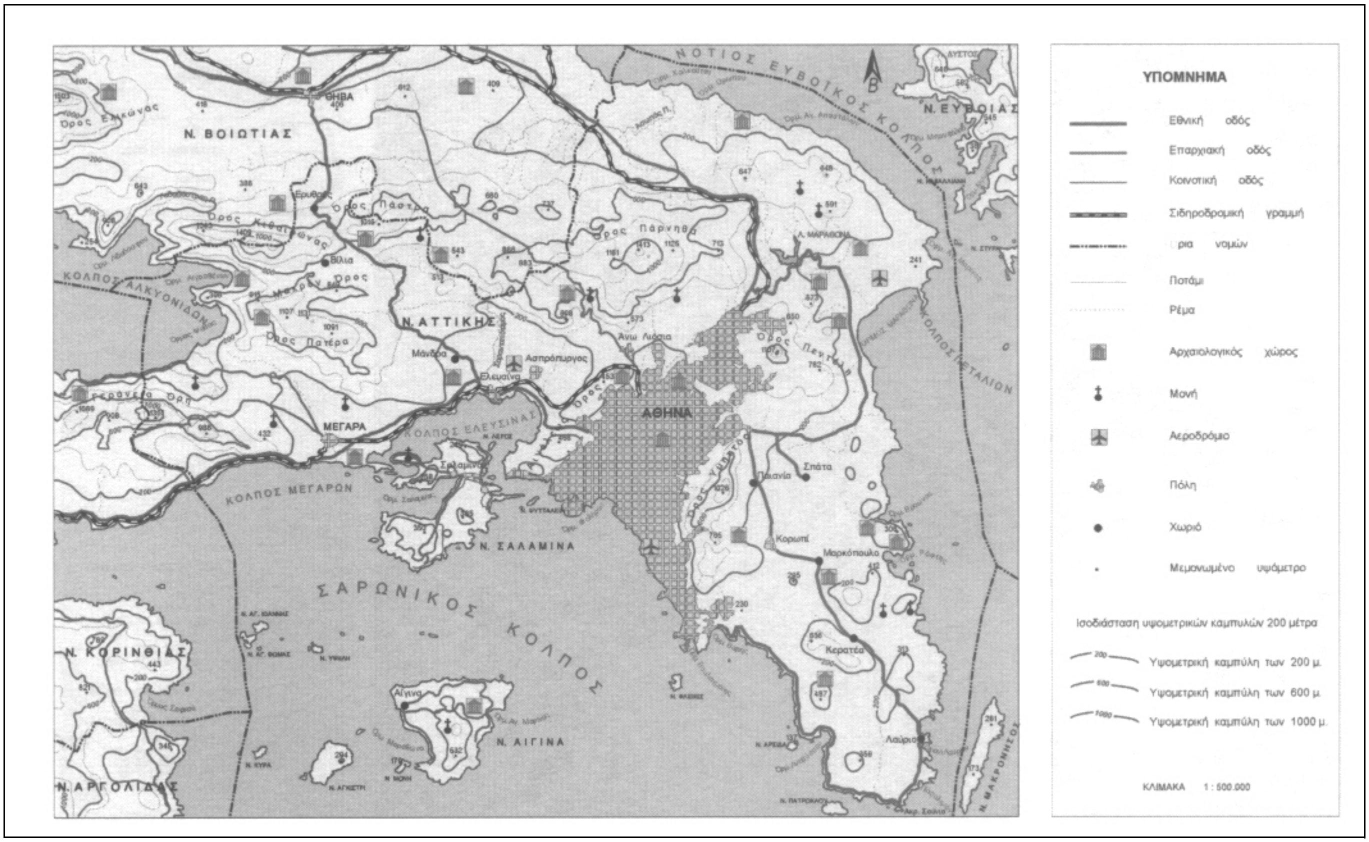

Figure 3a. The four maps of different landform representations: (a) contour lines (Cnt)

Table 14. Samples of questions of the "Representation of landforms" test

R1 (L1-L2):	Put "√" in the correct statement: Marathonas lake is located to the *north / south / east / west* of Spata.
R2 L1 (A1, A2, A3):	Put "√" in the correct statement: The town that has a railway and a highway passing through it is *Megara / Asporpyrgos / Thiva / Koropi.*
R2 (L1) X1 - (L2) X1:	Put "√" in the correct statement: Walking from Vilia to Mandra the elevation is *increasing / decreasing / the same.*
R2 (L1) X1 - (L2) X1:	Write the name of a village that lies (a) in the plain (b) on the mountain.

dix C lists all the questions, with the relative maps identified in parentheses. Seven questions, common to all questionnaires, examined spatial relationships not pertinent to landform, covering the four types of spatial relationships defined above: determining the topological relationship of vicinity, comparing routes, and determining direction on both north–south axis and east–west axes. Examples of these questions are presented in Table 14. The remaining four questions pertained to landform types on each map. Two questions were identical on all four questionnaires and concerned the comparison of elevation and the determination of decreasing or increasing elevation along a route. According to the kinds of relationships that could be extracted from the specific representation of landform, the other two questions concerned two of the following: comparison of slopes; determination of the hypsometric zone where a place is located; and determination of the elevation of hills. Examples of the second type are given in Table 14.

Twenty-four classes of Grades 3 through 6 (three classes per grade per school) were randomly selected from two elementary schools of the Attiki prefecture (Schools M and N). The total sample consisted of 718 students in Grades 3 (168), 4 (179), 5(166), and 6 (205) (see Table 15). Each student received a map and the corresponding questionnaire. In each class, all four map types were distributed. Children sitting close to each other received different maps.

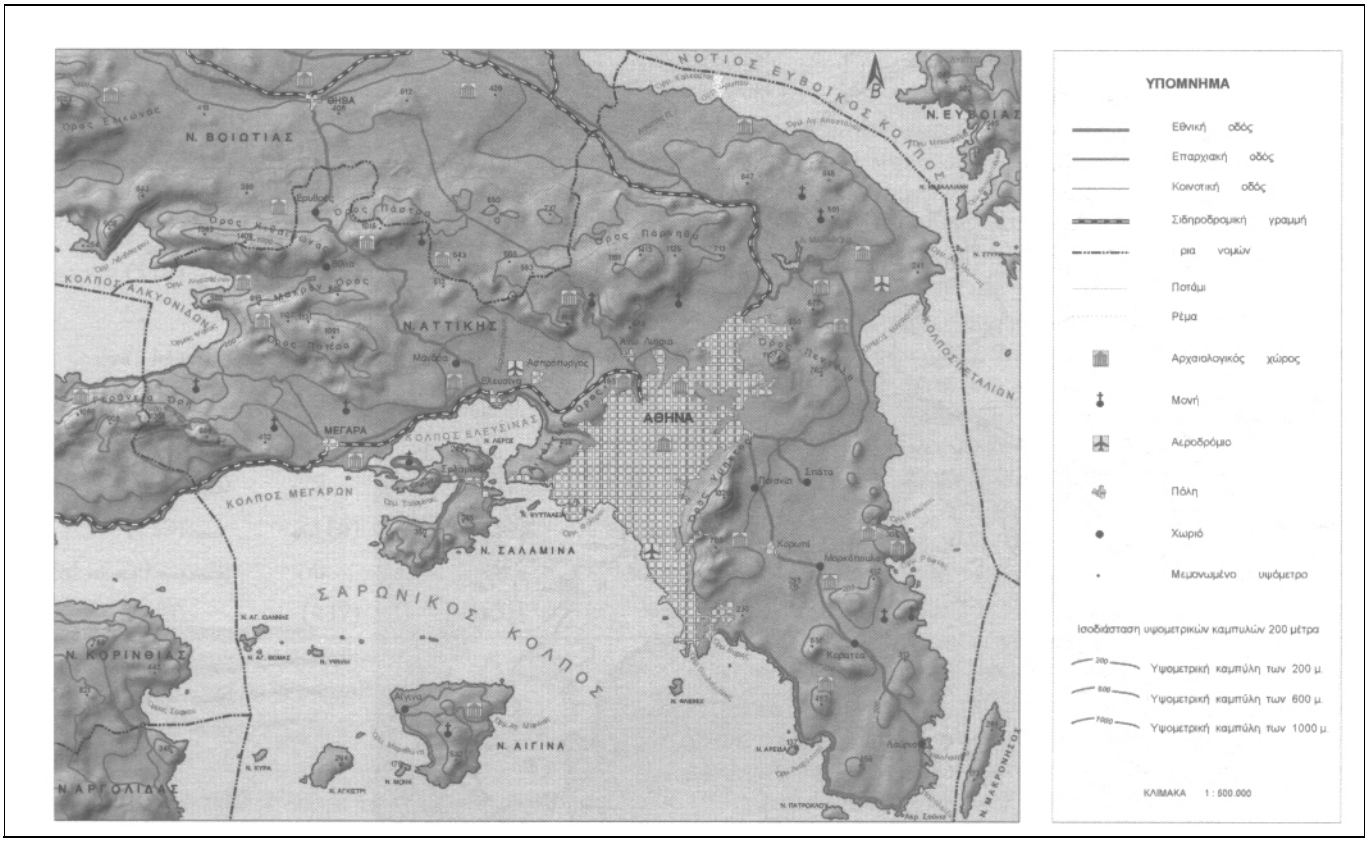

Figure 3b. The four maps of different landform representations: (b) combination of hill shading and contour lines (Sh/Cnt)

Table 15. Participants in the "Representation of landforms" test

	Sex	Grade 3	4	5	6	Total
School M (Attiki)	Boys	32	41	38	49	160
School N (Attiki)		41	43	45	47	176
Total		73	84	83	96	336
School M (Attiki)	Girls	42	47	43	54	186
School N (Attiki)		53	48	40	55	196
Total		95	95	83	109	382
Total		168	179	166	205	718

Results of the "Representation of Landforms" Test

The percentages of correct responses for each of the seven questions on planimetric information are presented in Table D8 and those for each of the six questions pertaining to landform in Table D9 (Appendix D). The number of participants is indicated in parentheses for each question. Application of the Mann-Whitney test did not reveal any significant difference in performance ($z = -1.798$, $p > 0.05$) between boys and girls in extracting spatial relationships from the four maps or between the two schools ($z = -1.155$, $p > 0.05$). The percentage of correct responses for the seven questions relating to all four maps, which focused on extracting spatial relationships not pertinent to landform, was used to calculate the mean score for each grade and for the total sample. Table 16 presents the mean score and standard deviation for each grade, as well as the results of the Jonckheere-Terpstra test, which found no significant effect ($p > 0.05$) of the method of landform representation on students' ability to analyse planimetric information. A more analytical examination of students' performance on these questions confirms the results of the "Scale and background complexity" test and the "Thematic layers" test. Determining the topological relationship of vicinity was an easy task, even for the youngest students. Furthermore, determining direction on the north–south axis appears to have been significantly easier than determining direction on the east–west axis. In the present test, the vast majority of Grade 3 students managed to compare routes on small-scale maps that had the same starting point and consisted of one segment.

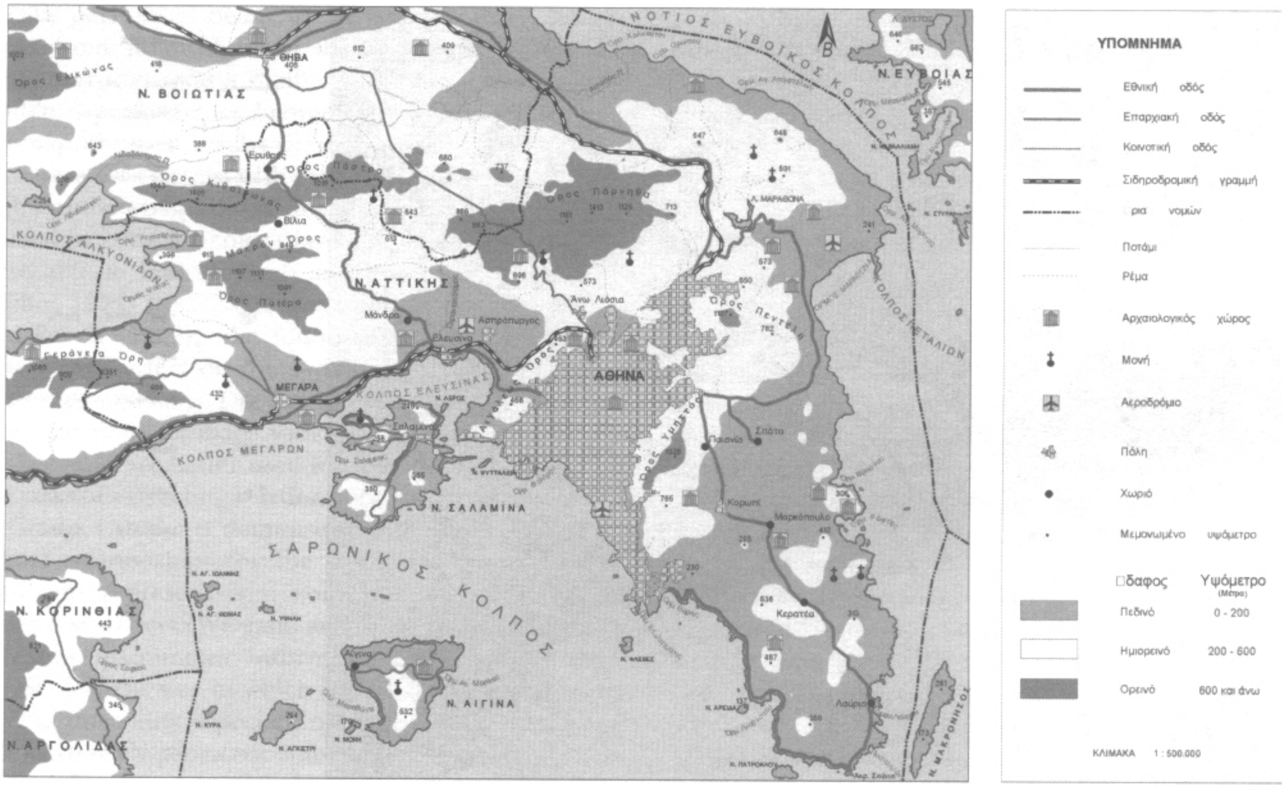

Figure 3c. The four maps of different landform representations: (c) hypsometric tints (HT)

Table 16. Percentage of correct responses in extracting planimetric information of the "Representation of landforms" test

	Cnt		Sh/Cnt		HT		Sh		Jonckheere-Terpstra test	
Grade	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***		
3	59	23	62	20	69	15	63	19	1.522	$p > 0.05$
	(44)		(47)		(41)		(36)			
4	70	20	73	19	72	16	72	18	0.294	$p > 0.05$
	(48)		(45)		(46)		(40)			
5	81	16	80	18	82	19	83	18	1.158	$p > 0.05$
	(42)		(42)		(41)		(41)			
6	84	17	81	15	80	18	86	12	0.274	$p > 0.05$
	(52)		(50)		(52)		(51)			
Total	74	21	74	20	76	18	77	19	1.603	$p > 0.05$
	(186)		(184)		(180)		(168)			

M = mean, *SD* = standard deviation
Number of participants in parentheses

As mentioned above, not all the questions concerning landforms could be applied to the four maps. Participants' scores on different maps were compared for each question. In comparing the elevation of two locations (higher, lower, the same) and determining the relative change of elevation between two locations (increasing, decreasing, staying the same), the mean scores for each grade and for the total sample did not show statistically significant differences ($p > 0.05$), according to the Jonckheere-Terpstra test. In locating villages lying between specific hypsometric lines from maps with contour lines (Cnt and Cnt/Sh), the mean scores for each grade and for the total sample did not reveal a statistically significant difference ($p > 0.05$) using the Mann-Whitney test. For each grade, the mean score for determining the steepest slope was higher on the map with hill shading (Sh) than on the two maps with contours (Cnt and Cnt/Sh). Application of the Jonckheere-Terptsra test revealed a significant difference ($p < 0.05$) in the scores for the total sample on the map with hill shading (Sh). For each grade, the mean score for the map with contour and hill shading (Cnt/Sh) was slightly higher than the mean score for the map with contours (Cnt) only. In determining the elevations of three hills on the hypsometric tints map (HT) and the hill shading

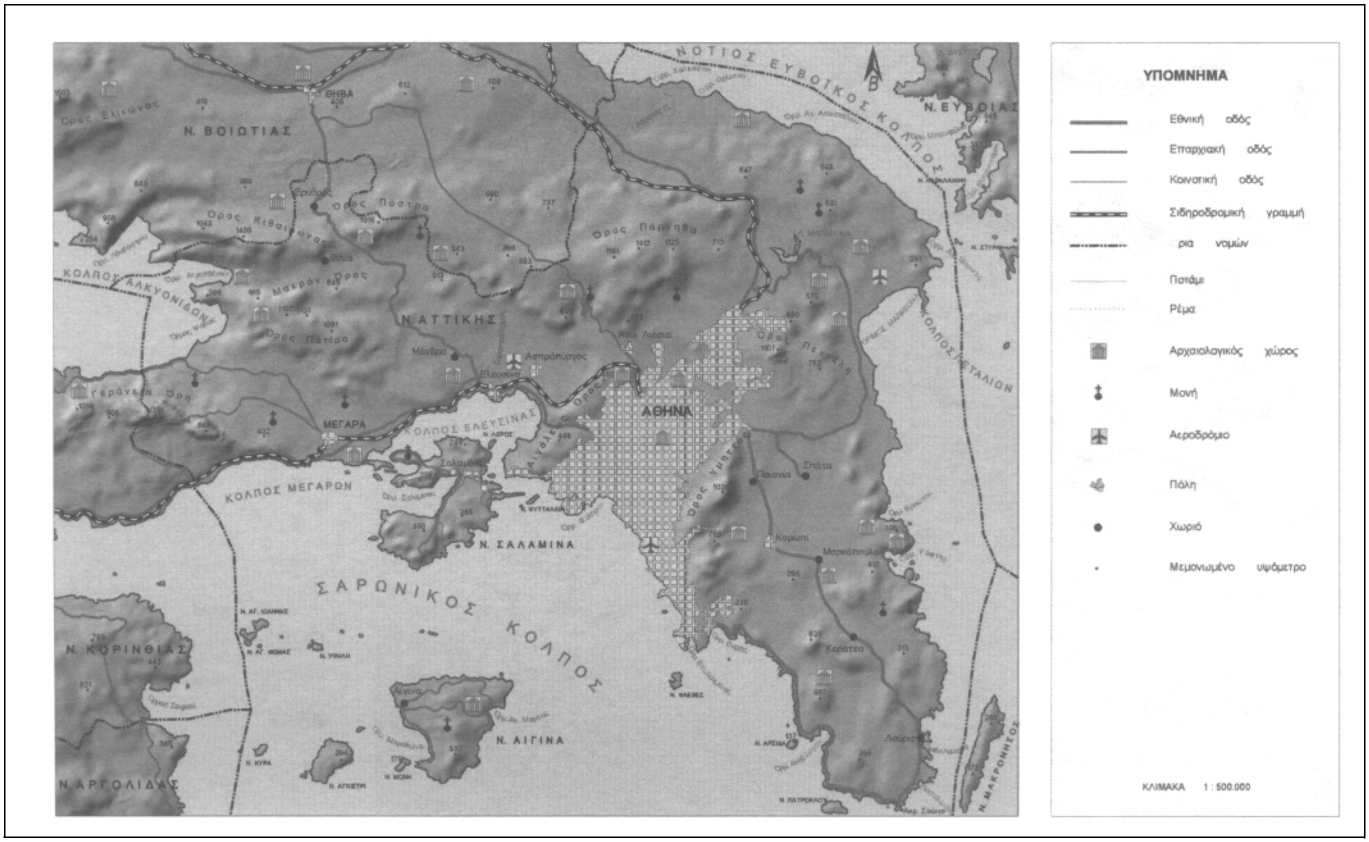

Figure 3d. The four maps of different landform representations: (d) hill shading (Sh)

map (Sh), the mean scores for Grades 5 and 6, as well as for the total sample, were significantly better ($p < 0.05$) for the hill shading map (Sh) than for the hypsometric tints map (HT).

In a similar test of legibility of four different types of relief maps, using participants from 16 to 18 years of age, no single type of map was found to be best for retrieving information about relief (Phillips, DeLucia, and Skelton 1975). In the current test, conducted with elementary school children, performance was better using the hill shading map (Sh). Considering that the participants did not have experience with this method of landform representation, it is obvious that hill shading assisted these young map readers, especially in visualizing the terrain.

Conclusions

This study used three sequential tests to examine the influence of map scale, background complexity, number of thematic layers, and method of landform representation on the ability of elementary school students (Grades 3 to 6) to analyse map content.

The scale of a general map affected the ability of elementary school children to analyse map content. In the aforementioned tests, when students' performance differed between small-scale and large-scale maps, it was usually the case that the score was significantly higher on the large-scale map for Grade 3 students, whereas for Grade 5 students, the score was significantly and systematically higher on the small-scale map. The difference in the Grade 5 students' performance may have been due to their experience with maps. Specifically, in geography classes, Grade 3 students had been exposed to maps at both scales, with an emphasis on large-scale maps; the same was true for Grade 4 students, but with emphasis on small-scale maps, whereas students in Grades 5 and 6 were exposed only to small-scale maps. The effect of map scale was not the same for all the relationships that could be obtained from the map. For example, students in all grades had significantly lower performance in tasks such as comparing routes, determining direction on the north–south axis, and counting characteristics enclosed in a district on large-scale maps as opposed to small-scale maps. However, they performed much better in determining direction on the east–west axis on a large-scale map. It is clear that the introduction of students to map content analysis can start with large-scale maps, but their use must not stop there.

The simple, monochromatic background of the political map proved more effective in enabling students to recognize spatial relationships that mainly concern locations, in contrast with the vivid background of the physical map with its conventional green, yellow, and brown hypsometric tints. Students in Grades 4, 5, and 6 systematically performed better in extracting spatial relationships from political maps than from physical maps. Whenever there was a significant difference in Grade 3 students' performance between the political and physical map, the best results were produced by the former. These results contrast with Miller's findings that fourth-, fifth-, and sixth-grade students were not seriously distracted by complex colour layers on a physical map and were able to look through and disregard colour array (Miller 1974, 1982). But they support those of Kempf and Poock (1969), who found that tints might have a detrimental effect on the two-dimensional information presented in a map. The results of the present study suggest that political maps with a simple monochromatic background are better used for introducing students to the tasks of extracting relationships among locations.

Grade 4 students demonstrated the ability to detect spatial relationships for the third dimension, that is, landform representation, confirming the findings of other researchers (Wiegand and Stiell 1997). The ability to extract planimetric information proved to be independent of the way in which the landform was presented. But the ability, especially of students in Grades 5 and 6, to extract hypsometric information that mainly concerned the interpretation of landforms was enhanced by the hill shading method, which gave visual realism to the representation. The hill shading application on maps is a function of slope, and students managed to determine the steepest slopes and to locate hills more successfully on the map with hill shading. It is worth mentioning that even Grade 6 students had difficulty in extracting information regarding landform when the hypsometric zones were defined by elevations, despite their familiarity with this method of representation.

The results indicate the need to represent landforms not only by the use of hypsometric tints, which has prevailed in school textbooks, but also by alternative methods such as hill shading, which lends visual support to the map reader and is very often applied in contemporary maps. Patrick Wiegand and Bernadette Stiell (1997) point out that there is widespread recognition that both children and adults find the conventions of relief mapping difficult to interpret. They suggest that "teachers could support children's understanding of relief mapping by introducing them to historical maps which typically use small pictures in elevation and hachures to represent hills" (1997, 191). The hill shading method can be considered an evolution of hachures (Robinson and others 1995). In contemporary topographic maps, it has prevailed as a method to provide both a clear representation of planimetric information and a visually realistic representation of the land surface.

Students in Grade 4 especially, to whom the symbolization and analysis of physical maps had recently been systematically introduced, performed better at analysing map content on physical maps with fewer thematic layers. But omitting thematic layers from small-scale maps with no vivid background (as in the cases of the population and the political maps) and from large-scale general maps resulted in simplistic representations that led to lower performance, especially for Grade 5 and 6 students, justifying Castner's (1990) argument that visually simplistic maps can be intellectually complex. The practice of simplifying maps in elementary textbooks by eliminating thematic layers should be reconsidered.

Relationships among locations do not present the same degree of difficulty, and in this study map scale influenced students' ability to extract them. The conception of topological relationships starts very early in child development (Piaget and Inhelder 1967). This is evident from the fact that the vast majority of students in Grade 3 could extract the topological relationship of places from both small- and large-scale maps and could define the relationship of vicinity between point symbols as well as between area symbols.

Students in all grades performed significantly better in comparing routes on small-scale maps than on large-scale maps. Grade 3 students could compare routes that had the same starting point and consisted of one segment, whereas Grade 4 students could compare more complex routes on small-scale maps. But even students in Grade 6 had difficulty in comparing routes or determining a route on a large-scale map. The students' poor performance on large-scale maps contradicts the findings of other researchers, which indicate that even preschoolers can draw a route on an aerial photograph (Blaut and Stea 1971) and follow routes presented on large-scale maps (Blades and Spencer 1986; Freundschuh 1990). But it must be pointed out that the issue of map understanding among young children is debated among researchers (Liben and Downs 1997; Blaut 1997). Furthermore, Lynn Liben and Roger Downs have stated that "map understanding indeed begins early, but it progresses through a complex and difficult sequence of developments that are simply not well understood at present" (1989, 193). Piaget and Inhelder (1967) maintained that by age six, children have the ability to compare the length of lines. But that ability only emerged, in the present study, with small-scale maps, on which roads were represented by linear symbols, and not on large-scale maps, on which roads were represented by area symbols. This deficiency may be attributable to a lack of adequate experience with large-scale maps. It is important to note that when line symbols indicated the routes on large-scale maps, half of the Grade 3 students compared their lengths successfully.

The relative difficulty of determining the direction on the east–west axis compared to the north–south axis cited by Tversky (1981) was confirmed for small-scale maps. Taking into account that determining directions on maps is a task that Grade 3 students are commonly asked to perform as part of their regular curriculum, the students' performance on the east–west axis can be considered poor.

Grade 3 students demonstrated the ability to extract relationships concerning the spatial distribution of an attribute from a thematic map representing the distribution of population with graduated point symbols (circles), even without previous experience with this symbolization. Children from the age of seven or eight have abilities of classification and ordering (Piaget and Inhelder 1967); the ability to order underlies Grade 3 students' performance on an abstract representation such as a map. In this study, they managed to compare the relative magnitudes of graduated point symbols and order four symbols according to the magnitude of population that the symbols represented. On the other hand, even Grade 6 students found it difficult to determine the specific numerical magnitude that point symbols represented. The difficulty of dealing with data of numerical scale compared to dealing with data of an ordered scale, at the concrete stage of development, has also been revealed by other researchers (Gerber 1984).

Relationships among various attributes in a single location and relationships of spatial distribution of two attributes were the most difficult for children to extract at both large and small scales. As expected, extracting spatial relationships of the third dimension, as in the case of landform representation, was more difficult than recognizing spatial relationships involving two-dimensional characteristics. Significant differences in the students' performance in detecting spatial relationships of different types appeared mostly in Grades 4 and 5, a level at which students are introduced systematically to the analysis of map content.

In this study, Grade 3 students, despite their limited mapping experience, were successful in extracting some spatial relationships from large- and small-scale general reference maps and from small-scale thematic maps, although they had had no previous exposure to thematic maps at school. Different map forms had less influence on the performance of Grade 3 students in analysing map content than they had on the performance of older students, and especially that of Grade 5 students. In school, students in Grades 4 and 5 are introduced to different map analysis tasks, whereas Grade 6 students repeat the same tasks for other geographical areas. Knowledge of how different map forms affect the performance of students at different grade levels in analysing map content is important for the design of maps for textbooks and for their strategic use by teachers.

This study has brought to light the need to use both small- and large-scale general and thematic maps in elementary grades 3 through 6. Maps with a limited number of thematic layers did not help students to analyse map content; political maps with monochromatic backgrounds were more helpful in extracting relationships among locations than maps with hypsometric tints. The hill shading method mostly helped older students to recognize relationships concerning landforms. Map forms other than those that have prevailed in education must be tested and introduced into elementary education in order to help students better develop their ability to analyse map content.

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Appendix A: Questions for the "Scale and background complexity" test

The map to which each question corresponds is given in parentheses.

1. Write the number of the villages presented in the Paphos district. (Physical map)
2. Paphos district neighbours on the district of *Kyrenia / Nicosia / Famagusta / Larnaca.* (Physical map)
3. Nicosia is located to the *north / south / east / west* of Famagusta. (Physical map)
4. The most distant route is from Nicosia to *Kyrenia / Famagusta / Paphos / Larnaca.* (Physical map)
5. A highway connects Nicosia with *Kyrenia / Limassol / Famagusta / Morfou.* (Physical map)
6. Write the name of a village that lies on the hills of the Nicosia district and has a river passing through it. (Physical map)
7. Write the name of a village that lies (a) in the plain (b) on the hill (c) on the mountain. (Physical map)
8. Travelling from Nicosia to Kyperounta the elevation is *increasing / decreasing / the same.* (Physical map)
9. Write the name of a village that lies in the hypsometric zone with elevation (a) from 0 to 200 metres, (b) from 200 to 800 metres, and (c) from 800 to 2,000 metres. (Physical map)
10. Write the number of the villages presented in the Limassol district. (Political map)
11. Kyrenia district neighbours on the district of *Paphos / Nicosia / Limassol / Larnaca.* (Political map)
12. Nicosia is located to the *north / south / east / west* of Kyrenia. (Political map)
13. The most distant route is from Paphos to *Kyrenia / Famagusta / Paphos / Larnaca.* (Political map)
14. A highway connects Nicosia with *Famagusta / Morfou / Larnaca / Kyrenia.* (Political map)
15. Write down the number of green places presented in the Limassol district. (Map of Limassol)
16. The court neighbours on the *school / museum / hotel / theatre.* (Map of Limassol)
17. The museum is located to the *north / south / east / west* of the court. (Map of Limassol)
18. The route in red is *equal to / shorter than / longer than* the route in blue. (Map of Limassol)
19. Put "√" on the restaurants that are located in green places. (Map of Limassol)
20. Draw a circle around the part of the footpath that is located next to a river and a fountain. (Map of Limassol)
21. Put an "X" on a building that is located at Makarios Avenue and neighbours on a green place. (Map of Limassol)
22. Circle the museum and the gallery. (Map of Limassol)
23. Draw on the map the shortest route from the museum to the gallery. (Map of Limassol)

Appendix B: Questions for the "Thematic layers" test

The maps to which each question corresponds are given in parentheses. For this test, many questions appeared on questionnaires relating to more than one map.

24. The Paphos district neighbours on the district of *Kyrenia / Nicosia / Famagusta / Larnaca.* (Ph1, Ph2, Pol1)
25. The most distant route is from Nicosia to *Kyrenia / Famagusta / Paphos / Larnaca.* (Ph1, Ph2, Ph3, Pol1, Pol2)
26. Nicosia is located to the *north / south / east / west* of Famagusta. (Ph1, Ph2, Ph3, Pol1, Pol2)
27. Kyrenia is located to the *north / south / east / west* of Nicosia. (Ph1, Ph2, Ph3, Pol1, Pol2)

28. Write the name of a village that it is located in the hills of the Nicosia district. (Ph1, Ph2)
29. Write the name of a village that lies on a plain in the Nicosia district and a river passes through it. (Ph1, Ph2)
30. Write the name of a village that lies (a) on the plain (b) in the hills (c) in the mountains. (Ph1, Ph2, Ph3)
31. Write the name of a village that lies in the hypsometric zone with elevation (a) from 0 to 200 metres, (b) from 200 to 800 metres, and (c) from 800 to 2000 metres. (Ph1, Ph2, Ph3)
32. Put "√" in the correct statement: *Nicosia has less population than Paphos / Larnaca has more population than Limassol / Limassol has more population than Paphos / Paphos has more population than Larnaca.* (Pop1, Pop2)
33. Write the name of a village that has a population of about 500 residents and a village that has a population of about 5,000 residents. (Pop1, Pop2)
34. Write the names of the four towns of Cyprus, according to the size of their population, from the biggest to the smallest. (Pop1, Pop2)
35. Put "√" in the correct statement: The settlements (towns and villages) that have the largest population are located on *plains / hills / mountains.* (Pop1)
36. Put "√" in the correct statement: The settlements (towns and villages) that have the largest population are located in zone with elevation *1–200 metres / 200–800 metres / higher than 800 metres.* (Pop1)
37. Put "√" in the correct statement: The Neapolis district neighbours on *the Agios Nektarios district / the Agia Zoni district / the Agia Triada district.* (Lim1, Lim2)
38. Put "√" in the correct statement: The route from the tennis court to the school is *equal to / shorter than / longer than* the route from the museum of physical history to the school. (Lim1, Lim2, Lim3)
39. Put "√" in the correct statement: The museum is to the *north / south / east / west* of the school. (Lim1, Lim2, Lim3)
40. Put "√" in the correct statement: The court is in the *north / south / east / west* of the museum. (Lim1, Lim2, Lim3)
41. Put "√" in the correct statement: *The court is located in the Neapolis district / The court is located in a green place / The theatre is located in the Agia Zoni district / The theatre is located in a green place.* (Lim1, Lim2)
42. Put "√" in the correct statement: *The court is located next to the river at the Agia Triada district / The playground is located in a green place at the Agia Zoni district / The theatre is located next to the river at the Neapolis district / The school is located at a green place at the Agia Zoni district.* (Lim1, Lim2)
43. Put "√" in the correct statement: Walking in 28th Octovriou Street I come across *a bank and an art-gallery / an art-gallery and a hotel / a hotel and a school / a café and a museum.* (Lim1, Lim2, Lim3)
44. Put "√" in the correct statement: *The bank is located in a smaller building block than the fast food / The petrol station is located in a smaller building block than the bank / The petrol station is located in a larger building block than the fast food.* (Lim1, Lim2, Lim3)

Appendix C: Questions for the "Representation of landforms" test

The maps to which each question corresponds are given in parentheses. For this test, many questions appeared on questionnaires relating to more than one map.

45. Put "√" in the correct statement: *The Voiotia prefecture neighbours on the Argolida prefecture / the Korinthia prefecture neighbours on the Evoia prefecture / The Voiotia prefecture neighbours on the Attiki prefecture.* (Cnt, Sh/Cnt, HT, Sh)
46. Put "√" in the correct statement: The most distant route is from Mandra to *Elefsina / Megara / Thiva / Aspropyrgos.* (Cnt, Sh/Cnt, HT, Sh)
47. Put "√" in the correct statement: Spata is located to the *north / south / east / west* of Paiania. (Cnt, Sh/Cnt, HT, Sh)
48. Put "√" in the correct statement: Marathonas Lake is located to the *north / south / east / west* of Spata. (Cnt, Sh/Cnt, HT, Sh)
49. Put "√" in the correct statement: The town that has a railway and a highway passing through it is *Megara / Asporpyrgos / Thiva / Koropi.* (Cnt, Sh/Cnt, HT, Sh)
50. Write the names of two villages that you pass through when travelling from Thiva to Elefsina. (Cnt, Sh/Cnt, HT, Sh)
51. Write the name of an island that has antiquities and a monastery. (Cnt, Sh/Cnt, HT, Sh)
52. Put "√" in the correct statement: Mandra is located at an elevation that is *the same as / lower than/ higher than* Vilia. (Cnt, Sh/Cnt, HT, Sh)
53. Put "√" in the correct statement: Walking from Vilia to Mandra the elevation is *increasing / decreasing / the same.* (Cnt, Sh/Cnt, HT, Sh)
54. Put "√" in the correct statement: *Makron Oros Mountain has a steeper slope than Kithaironas Mountain / Penteli Mountain has a steeper slope than Kithaironas Mountain / Kithaironas Mountain has a steeper slope than Makron Oros Mountain.* (Cnt, Sh/Cnt, Sh)
55. Write the name of a village that lies (a) on the plain (b) in the mountains. (HT)
56. Write the name of a village that lies in the hypsometric zone with elevation (a) from 0 to 200 metres, (b) from 200 to 600 metres. (Cnt, Sh/Cnt)
57. Write the elevations of three hills that are located round Mount Keratea, from the highest to lowest. (HT, Sh)

Appendix D

Table D1. Percentage of correct responses for the physical map on the "Scale and background complexity" test

	Q1		Q2		Q3		Q4		Q5		Q6		Q7		Q8		Q9	
Grade	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
3	33	47	79	41	4	19	40	49	74	44	36	48	45	50	51	59	13	34
4	58	50	74	44	34	48	58	50	88	33	38	49	61	49	49	50	26	44
5	64	48	80	40	45	50	54	50	89	31	59	49	79	41	61	49	45	50
6	87	34	94	23	57	50	65	48	99	10	62	49	78	41	74	44	52	50
Total	60	49	82	38	35	48	54	50	87	33	49	50	66	47	59	49	34	48

M = mean, *SD* = standard deviation

Table D2. Percentage of correct responses for the political map on the "Scale and background complexity" test

	Q10		Q11		Q12		Q13		Q14	
Grade	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
3	44	50	90	31	17	38	80	40	61	49
4	67	47	90	29	46	50	81	40	79	41
5	76	43	95	22	51	50	91	29	87	33
6	92	28	96	19	75	43	92	28	90	31
Total	70	46	93	26	48	50	86	34	80	40

M = mean, *SD* = standard deviation

Table D3. Percentage of correct responses for the map of Limassol on the "Scale and background complexity" test

	Q15		Q16		Q17		Q18		Q19		Q20		Q21		Q22		Q23	
Grade	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
3	28	45	82	39	40	49	47	50	70	46	20	40	40	49	63	48	24	43
4	31	46	90	29	66	48	49	50	63	48	24	43	39	49	71	46	35	48
5	16	37	95	22	56	50	64	48	70	46	28	45	44	50	77	42	40	50
6	68	47	94	23	73	45	78	41	79	41	42	50	55	50	86	35	55	50
Total	35	48	91	29	59	49	60	49	70	46	28	45	44	49	74	44	38	49

M = mean, *SD* = standard deviation

Table D4. Percentage of correct responses for physical maps on the "Thematic layers" test

	Q24		**Q25**		**Q26**		**Q27**		**Q28**		**Q29**		**Q30**		**Q31**	
Grade	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
3	68	47	41	49	20	40	46	50	38	49	36	48	39	49	8	28
	(114)		(170)		(170)		(170)		(114)		(114)		(170)		(170)	
4	72	45	63	48	16	40	66	48	50	50	34	48	63	48	27	44
	(111)		(169)		(169)		(169)		(111)		(111)		(169)		(169)	
5	90	30	79	41	33	47	72	45	81	42	64	48	80	40	31	46
	(105)		(154)		(154)		(154)		(105)		(105)		(154)		(154)	
6	88	32	79	40	48	50	76	43	81	39	62	49	83	37	45	50
	(119)		(174)		(174)		(174)		(119)		(119)		(174)		(174)	
Total	79	40	65	48	29	45	64	48	63	48	50	50	65	48	27	45
	(449)		(667)		(667)		(667)		(449)		(449)		(667)		(667)	

M = mean, *SD* = standard deviation
Number of participants in parentheses

Table D5. Percentage of correct responses on political maps of the "Thematic layers" test

	Q24		**Q25**		**Q26**		**Q27**	
Grade	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
3	72	45	38	49	20	40	51	50
	(52)		(111)		(111)		(111)	
4	80	40	68	47	29	46	82	39
	(56)		(111)		(111)		(111)	
5	84	37	84	36	36	48	72	45
	(55)		(110)		(110)		(110)	
6	92	28	86	35	59	49	83	38
	(59)		(119)		(119)		(119)	
Total	82	38	69	46	36	48	72	45
	(222)		(451)		(451)		(451)	

M = mean, *SD* = standard deviation
Number of participants in parentheses

Table D6. Percentage of correct responses for population maps on the "Thematic layers" test

	Q32		Q33		Q34		Q35		Q36	
Grade	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
3	73	45	19	40	54	50	41	50	12	33
	(114)		(114)		(114)		(59)		(59)	
4	86	34	31	46	66	48	42	50	21	41
	(111)		(111)		(111)		(57)		(57)	
5	88	32	46	50	77	42	61	50	31	47
	(105)		(105)		(105)		(52)		(52)	
6	98	13	53	50	78	42	70	46	66	48
	(119)		(119)		(119)		(61)		(61)	
Total	87	34	37	48	69	46	54	50	33	47
	(449)		(449)		(449)		(229)		(229)	

M = mean, *SD* = standard deviation
Number of participants in parentheses

Table D7. Percentage of correct responses for Limassol maps on the "Thematic layers" test

	Q37		Q38		Q39		Q40		Q41		Q42		Q43		Q44	
Grade	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
3	65	48	18	38	40	49	29	46	51	50	40	49	52	50	44	50
	(105)		(167)		(167)		(167)		(115)		(115)		(167)		(167)	
4	84	37	22	41	31	46	45	50	53	50	39	49	70	46	62	49
	(113)		(169)		(169)		(169)		(113)		(113)		(169)		(169)	
5	87	34	25	44	45	50	50	50	67	47	54	50	79	41	64	48
	(104)		(159)		(159)		(159)		(104)		(104)		(159)		(159)	
6	88	32	41	50	59	49	56	50	87	34	63	48	86	35	82	39
	(115)		(174)		(174)		(174)		(115)		(115)		(174)		(174)	
Total	81	39	27	44	44	50	46	50	65	48	49	50	72	45	64	48
	(447)		(669)		(669)		(669)		(447)		(447)		(669)		(669)	

M = mean, *SD* = standard deviation
Number of participants in parentheses

Table D8. Percentage of correct responses for planimetric information on the "Representation of landforms" test

	Q45		**Q46**		**Q47**		**Q48**		**Q49**		**Q50**		**Q51**	
Grade	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
3	65	48	87	90	35	49	68	47	70	46	43	50	74	44
	(168)		(168)		(168)		(168)		(168)		(168)		(168)	
4	87	34	91	28	48	50	73	45	80	40	35	48	89	32
	(179)		(179)		(179)		(179)		(179)		(179)		(179)	
5	88	32	93	25	58	50	84	36	90	30	61	49	96	19
	(166)		(166)		(166)		(166)		(166)		(166)		(166)	
6	92	28	96	20	58	50	83	37	95	22	60	49	96	20
	(205)		(205)		(205)		(205)		(205)		(205)		(205)	
Total	84	37	92	27	50	50	77	42	84	36	50	50	89	31
	(718)		(718)		(718)		(718)		(718)		(718)		(718)	

M = mean, *SD* = standard deviation
Number of participants in parentheses

Table D9. Percentage of correct responses pertinent to landform of the "Representation of landforms" test

	Q52		**Q53**		**Q54**		**Q55**		**Q56**		**Q57**	
Grade	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
3	48	50	46	50	46	50	34	48	12	33	34	48
	(168)		(168)		(127)		(41)		(91)		(168)	
4	68	47	55	50	57	50	54	50	24	43	62	49
	(179)		(179)		(133)		(46)		(93)		(179)	
5	75	44	67	47	66	48	63	49	19	40	76	43
	(166)		(166)		(125)		(41)		(84)		(166)	
6	81	39	68	47	71	45	58	50	15	36	76	43
	(205)		(205)		(153)		(52)		(102)		(205)	
Total	69	46	59	49	60	49	53	50	17	38	63	48
	(718)		(718)		(538)		(180)		(370)		(718)	

M = mean, *SD* = standard deviation
Number of participants in parentheses