European Journal of Geography **2 2**: 35-47, 2011.
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CHILDREN'S MAP READING ABILITIES IN RELATION TO DISTANCE PERCEPTION, TRAVEL TIME AND LANDSCAPE

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Abstract
Children's cognition of distance is influenced by functional distance and estimations of travel time which increases with the presence of natural or artificial barriers. In this paper we investigate pupil's associations of landscape and travel time in a map reading task of equal distance target cities. More than 330 11 year old pupils attending the fifth grade from 18 public primary schools located in city and rural areas participated in a research with the use of a 3D relief map of central Greece for decision making activities relating travel time to geomorphologic barriers. We hypothesized that pupils from city areas would design straight line routes regardless of the physical landscape influenced by the linear and rectangular outlines of city environments in opposition to pupils living in rural areas that would design curved routes according to the landscape. The results indicate that children relate landforms with travel time by identifying physical obstacles on the map. Pupils that selected the city of destination correctly justified their answers by identifying geomorphologic features on the map. However, the performance of urban pupils outpaces rural pupils' performance postulating that the quality and quantity of educational resources in city areas may influence positively spatial cognition.

Keywords: *route selection, route depiction, morphological barriers, 3D relief map*

1. INTRODUCTION

Wayfinding is an everyday task, essential to survival, that has been accomplished by people since they evolved and by other organisms before that, using their eyes and bodies and minds (Tvesrky, 2000, p. 24)

It is argued (Kosslyn et al., 1974) that children's spatial representations rely on functional distance and their estimations of traveled distance increases with the presence of natural or artificial barriers. Functional distance is described as the length of traveled route while moving between locations (Cohen et al, 1978).

According to the route segmentation hypothesis (Allen, 1981) traveled routes segmented by features are considered longer than unsegmented routes. Barriers influence the cognitive spatial organization by chunking the space into local subspaces (Newcombe & Liben, 1982) leading to distorted estimations. Both preschoolers and adults were found to overestimate the distance between locations separated by opaque barriers, but children focused on the required effort to move from one location to another, while adults were influenced by visual distance information (Kosslyn et al., 1974). Cohen and his colleagues' research (1978) on distance estimations of 9-10 year old children and adults demonstrated the consistent effect of hills and sloping pathways as a factor of added effort, which resulted in overestimation of distances. Circuit routes between locations revealed similar overestimations of actual inter-object distances contrary to direct tracks by kindergartners (Anooshian & Wilson, 1977).

Increased experience, exposure and interaction with the physical environment improve environmental awareness (Golledge & Stimson, 1997; Thorndyke & Hayes-Roth, 1982). Visits to rivers by upper primary school children aged 9-11 from four different schools living in outer urban London areas had a positive effect on their perceptions of rivers (Tapsell et al. 2001). Mackintosh (2005) underlines the importance of providing children with experience of rivers and fieldwork, as they reinforce landscape visualization and the development of three-dimensional constructions of rivers that supports classroom activities on associations and terminology.

Children's perception of the third dimension on maps (altitude) is influenced by their natural surroundings (Labrinos, 2009, Trend et al. 2000). Research based on findings from more than 2000 12 year old primary pupils in more than 100 Central Macedonian schools, Greece on the representation of the third dimension on maps found that children living in mountainous and semi-mountainous regions had better understanding of relief in comparison with children living in coastal or plain areas (Lambrinos et al., 2000). Klonari et al. (2011) studied the perceptions and interpretations of terraces in terms of various uses and values between more than 360 primary and secondary students and more than 90 geography teachers and found that responders from rural areas had a better understanding of terraces than those from urban areas. On the contrary, restrictions on children's spatial mobility as a result of adult concerns over their use of public space and the extended privatization of rural space question the previous line of thought (Smith & Barker, 2001). Furthermore, the increased engagement with computer games reduces the chances of outdoor activities (Subrahmanyam et al, 2000; Palmer, 2006). However Chen & Michael (2005) supported that electronic games provide possibilities for the transformation of the process of knowledge construction and Buckingham (2007) argues that computer games can provide powerful learning experiences when effective learning principles are employed.

Uttal (2000) supports that understanding the symbolic nature and abstract representations of maps is less likely to be spontaneously developed than learned and children's spatial conception limitations may rely on restricted understanding of the functions and uses of maps, calling for the nurturing of special visual literacy skills (Kemp, 2008) and spatial literacy (Gryl et al., 2010). Enriching environmental experiences with map uses contributes to spatial competence. Parental map use and map resources available in the home improves children's map reading abilities and other spatial skills (Liben & Myers, 2007). "Meaningful verbal annotations" provided by parents during travel positively influences the quality of pupils' representations of the landscape (Hart, 1981).

These studies provide evidence that morphologic barriers, environmental experience, engagement with electronic games and parental map uses influence spatial awareness and map reading abilities.

Spatial thinking is a domain of great scientific interest within the disciplines of child psychology (Gersmehl & Gersmehl, 2007), geography, earth and environmental sciences (GEES) (King, 2006) and a key organizing principle for geography education (Bednarz et al. 2009). Gersmehl (2005) suggested a taxinomy of spatial-thinking concepts to geography instruction at all levels, while Jo & Bednarz (2009) proposed a taxonomy of spatial thinking as a tool to select spatial questions in schools (Jo et al., 2010). Research on concepts of space, tools of representation and the processes of reasoning indicate they dynamically influence geography curricula and didactical methologies.

In this research the aim was to examine pupils' distance perception and their ability to design a route traveled by car according to the physical landscape. Therefore we used 3D maps as a research tool in our methodology. The challenge was for them to identify elements of the landscape such as mountains and plains and relate these features to the design of a route. The second aim was to explore whether familiarity with mountainous environments influenced their perception of geomorphologic features on the map and the selection of a route that would be traveled by car in the shortest period of time. We analyzed children's argumentation as well as their designs of selected routes according to the landscape. It was hypothesized that pupils from city areas would design straight line routes regardless of the physical landscape as they are influenced by the linear and rectangular outlines of city environments in comparison with rural pupils who would design more curved routes based on the "contours" of the natural landscape.

2. EXPERIMENTAL METHOD

2.1. Sample

A total of 339 pupils aged 11 attending the fifth grade from 18 public primary schools in Greece participated in the research. 80,5% of the pupils lived in city and inner-city areas and 19,5% lived in rural areas, following the distribution of the Greek population (NSSG, 2008). Over 70% of the children lived in coastal and plain areas (altitude < 250m) and 23,9% in semi-mountainous areas (altitude > 250m) and 5,6% in mountainous areas (altitude > 500m).

2.2. Materials

Pupils individually completed a questionnaire, which contained closed and open ended questions based on a 3D relief map of central Greece retrieved by the educational software "Traveling with maps in Greece and around the World" (Figure 1). The criteria for the selection of the map were the display of an area that contained three cities with equal road distance (110km) from the city-point of departure. It was also mentioned to the children that the quality of the road system was similar in all three routes. The Euclidian distance between (i) Amfissa and Lamia was 5cm, between (ii) Karpenisi and Lamia 7cm and between (iii) Livanates and Lamia 7,5cm. In the first option, two thirds of the route would be traveled through mountainous areas, in the second option one fifth of the route would be traveled through mountainous areas and in the third option the majority of the route was traveled through plain areas.

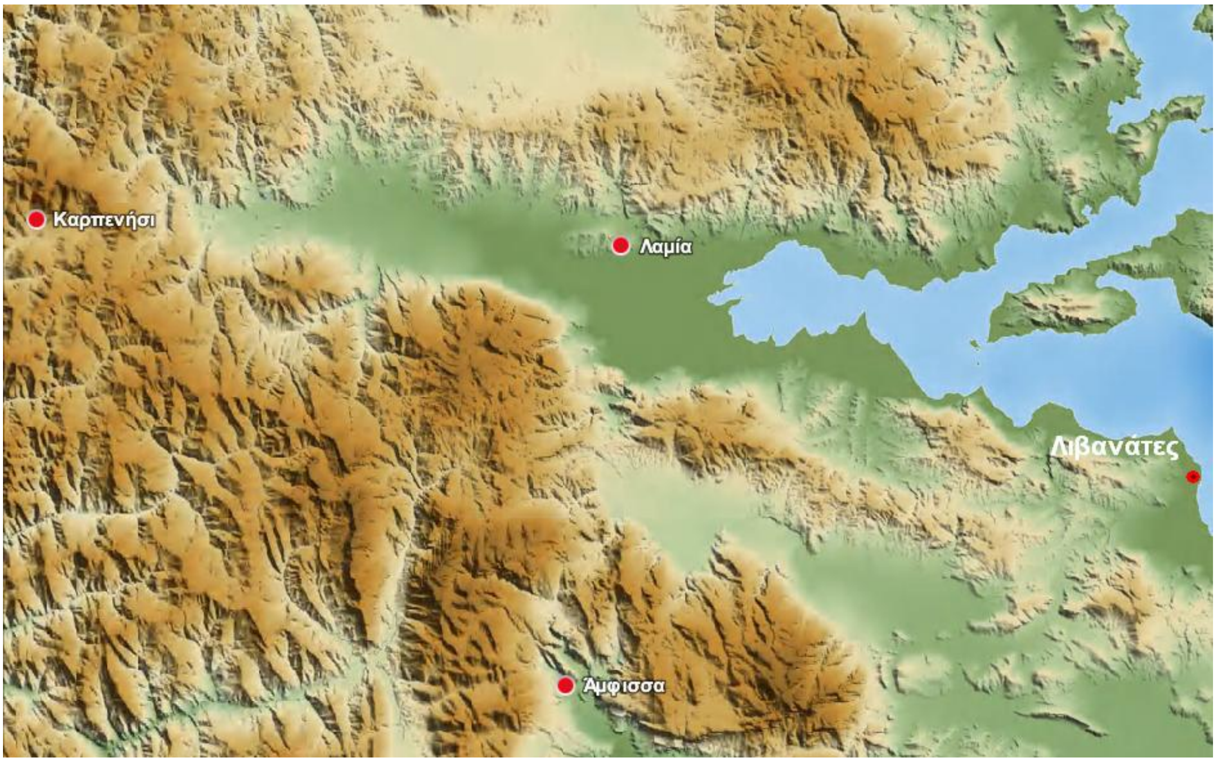

Fig.1. 3D relief map of Sterea Ellada. Source: Traveling with maps in Greece and in the World. (Source: Talent S.A.)

2.3. Procedure

The research was conducted during the third trimester of studies in Greek public primary schools by pupils attending the fifth grade. Permission was issued by the Pedagogical Institute and the schools' directors. The questionnaire was completed with the presence of the experimenter within a didactical hour (50 min) during the Geography class. Pupils were informed about the purpose of the study and were presented with the questionnaire. Finally it was mentioned that their performance would not influence their grades.

After observing the 3D map of southern Sterea Ellada on their questionnaires, the task was to select which of the three cities could be reached in the shortest period of time by driving a car. Then they were asked to justify their selection and design on the map the route they would follow by car.

2.4. Data analysis

City selections were scored as correct or false. A chi-square analysis was conducted to reveal statistical significance separately between the score and pupils' sex, the categories of engagement with electronic games (frequent, seldom, rare-none) and pupils' city or rural allocation. The data were categorical. The level of significance was $p<.05$ (Pathak, 2008).
We developed three level descriptors (Martin, 2008) and allocated each map combined with pupils' explanations to one of the three categories.

Relief associations. Pupils in this category selected Livanates as the city of destination, designed the route according to the landscape using curved lines between hills and mountains and produced explanations demonstrating a clear understanding of the physical landscape.

Linear associations. In this category pupils designed straight-line routes regardless of the landscape. The majority chose Karpenisi as the city of destination and produced explanations that revealed misunderstanding of the symbology of the point symbol of cities. In their explanations they demonstrated partial understanding of the landscape represented on the map. Straight lines were used to link the city of departure with the city of destination.

Naive theories. Pupils' designed either straight line or curved routes on the map regardless of the landscape. Their explanations were focused on prior visits to the city of destination and acquaintance with the region, personal impressions and environmental affordances (Tapsell et al., 2001) without further justification (eg. I chose Amfissa because I think so) or irrelevant responses (eg. We reach Livanates easier by boat).

3. RESULTS

3.1. City selection

Pupils' selection of cities on the map was scored as correct for Livanates and incorrect for Karpenisi and Amfissa. 64,3% of pupils answered correctly, while 35,7% answered incorrectly or gave no answer. 71,8% of the boys and 57,4 % of the girls selected correctly the city of destination. A chi-square analysis of these frequencies point that their distribution was significantly different to that expected by chance, χ^2 (1,339) = 0.006, $p < .05$. Significantly more boys made correct city selections.

Frequent engagement with electronic games is not related to high scores in the city selection task. 56% of the pupils who gave correct answers were occupied with electronic games more then three times per week. 8,3% of pupils were occupied with electronic games once a month and 35,7% had scarce or no involvement at all, $\chi 2$ (2,339) = 0.231, p>.05, ns.
Urban pupils presented better performance in the city selection task than rural population (Table 1). This proved to be highly significant, χ^2 (1,339) = 0.001, $p < .05$.

Table 1. Gender and route design

			Route design			
			Straight line	According to the landscape	NA	Total
Gender	Boy	Count	42	95	26	163
		% within sex	25,8%	58,3%	16,0%	100,0%
	Girl	Count	63	85	28	176
		% within sex	35,8%	48,3%	15,9%	100,0%
	Total	Count	105	180	54	339
		% within sex	31,0%	53,1%	15,9%	100,0%

3.2. Route design

More than half the participants designed the route according to the landscape (Figure 2). This is consistent with previous researches on river depiction on maps, where less then 60% of pupils designed the river flow on a 3D map according to the landscape (Apostolopoulou & Klonari, 2011) and on children's understanding of the physical landscape with maps, where more than 10% of pupils ignored the landform and drew routes in straight lines across mountains (Apostolopoulou et al., 2009).

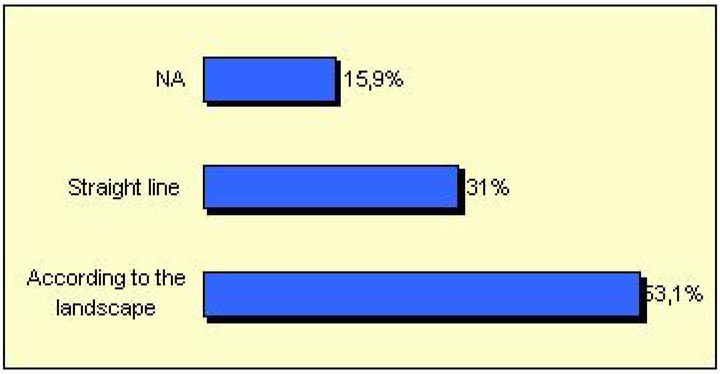

Fig.2. Route design

10% more boys more than girls designed on the map routes according to the landscape (Table 2), but the difference is not statistically important, χ^2 (2,339) = 0.114, p >.05, not significant. Among the pupils that designed routes according to the landscape 50,6% stated frequent engagement with electronic games, 10% were seldom engaged and 39,4% had rare or no involvement. There was no significant difference, χ^2 (4,339) = 0.673, p>.05, ns.

Children living in city areas designed routes according to the landscape on their maps in significantly greater frequency than children living in rural areas. City pupils presented better performance in the route design task (54, 6% designs according to the landscape), than rural population (47% designs according to the landscape). This proved to be highly significant, χ^2 (2,339) < 0.001, p <.05.

Some pupils (14, 2%) selected the city of destination correctly but drew straight line routes. This implies that they may understand the relief as it is represented on the map, but they find it difficult to design the route according to the landscape. Teachers should therefore combine map reading and map drawing activities to bridge this cognitive gap.

Table 2. Types of responses in justification of route design task

	Urban population	Rural population
A. There are more/less mountains/plains, the route is smooth, less natural obstacles	65,9%	45,5%
B. The route is in straight line, it's closer	18,3%	41,0%
C. It's easier to reach	4,8%	4,5%
D. I have been there, I have traveled there	1,1%	0,0%
E. I like it, I think so	5,9%	4,5%
F. NA	4,0%	4,5%
Total	100,0%	100,0%

3.3. Levels of understanding

Children were asked to justify city selections in an open ended question. Their answers were categorized in relief associations, linear associations and naïve theories as analyzed on the section Experimental Method.

Relief associations presented the highest frequency among the other levels of understanding (Figure 3). The majority of pupils mentioned geomorphologic features in their explanations that were identified on the map. However some children's explanations were influenced by familiarity with the region, aesthetic or leisure criteria.

> "I chose Amfissa because it is closer to my village" (Dimitra)
> "I chose Karpenis because I have been there and it is wonderful" (Ageliki)
> "I want to go to Amfissa, because I like the city" (Antonis)
> "I will go to Karpenisi to do climbing" (Nikos)
> "In the other places there is a lot of climbing and I get dizzy" (Eleni).

These justifications highlight a potential drawback on allocentric representations that, according to Piaget & Inhelder (1969), develop after the age of 8.

70,6% of the boys and 60,2% of the girls made relief associations justifying city selection and route design. Frequent engagement with electronic games was related to relief associated explanations, although no statistical significant difference was derived from a chi-squared analysis. 55,2% of pupils presenting relief associations in their answers noted a frequent engagement with electronic games, 8,1% rare engagement and 36,7% rare or no engagement at al. χ^2 (4,339) = 0.694, $p>.05$, ns.

Significantly more pupils in urban areas presented scientific oriented associations linking landscape with travel time and distance perception. 70% of the pupils living in city areas and 45, 5% pupils in rural regions identified geomorphologic features. 21, 2% of the city pupils explained city selection by postulating that it was closer or in straight line with the city of departure. The equivalent rural population reached 47%. Naïve theories were 8, 8% for city pupils and 7, 6% for rural pupils. This data is significant, χ^2 (2,339) < 0.001, $p < .05$.

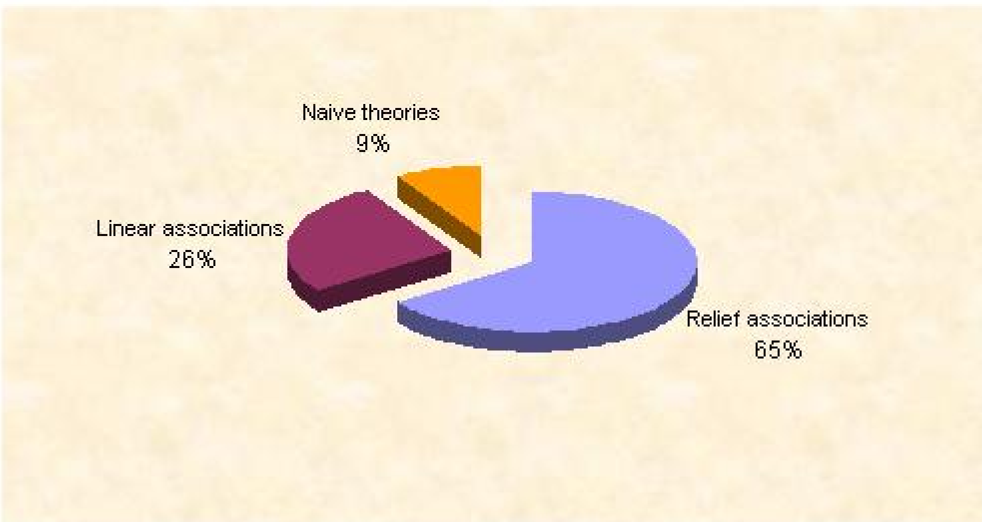

Fig.3. Levels of understanding

3.4. Odds ratio analysis

The results of the study indicate that urban pupils performed better in the city selection task, they designed routes on the map according to the landscape and justified city selections by identifying geomorphologic features. According to the logistic regression statistical technique we proceeded to an odds ratio analysis between the urban and rural pupil populations.
j, k the two categories of the variable pupils from urban and rural areas, where j = urban and k = rural.
j = 1, 2, 3 …n the criteria of route selection
where 1 = geomorphologic features, 2, 3 …n are the other criteria (ex. linear etc)

$$\text{odds}_j = \frac{F(x_j 1)}{F(x_j 2 + x_j 3 + \ldots x_j n)}$$

$$\text{odds}_k = \frac{F(x_k 1)}{F(x_k 2 + x_k 3 + \ldots x_k n)}$$

$$\text{Oddsratio} = \frac{\text{odds}_j}{\text{odds}_k} = \frac{1{,}22}{0{,}83} = \frac{1{,}47}{1}$$

Therefore an urban pupil was more likely to use geomorphologic features in justifying answers than a pupil from rural regions. These findings are supported by Blades' et al. (1998) research showing that urban pupils demonstrate developed map reading abilities. In addition Matthews et al. (1999) claimed that for many young people, rural childhoods and closer affinity to nature is on dispute. Research findings by Klonari et al. (2011) indicate that terraces escape the attention of rural students and teachers, suggesting that the apparent is not at all evident, even for the locals where terraces constitute a very common landscape feature. Even children living near to the River Thames have little sense of it (Taylor, 1995). Environmental experiences of children living in rural regions do not reflect on the better understanding of physical landscape on maps. Our research findings contradicted the nativist viewpoint that children's ability to understand maps is innate or acquired in early ages (Blaut 1991).

4. DISCUSSION

In this research we studied middle school children's map reading abilities in relation to distance perception, route traveling time and landscape with the use of a 3D relief map of Sterea Ellada.

The findings contradict our research hypothesis that pupils living in rural areas have a better perception of the landscape. Urban pupils presented better performance in the city selection task, they drew routes on the map according to the landscape and supported their city selections identifying geomorphologic features. Map reading abilities tend to be more advanced among urban children, a conclusion that is consistent with research findings of Blades et al. (1998) that map reading abilities are present in urban communities with relatively high adult-literacy rates.

Boys performed slightly better than girls in map reading tasks, while statistical significance was reported only in the city selection task, evidence supported by the studies of

Johnson and Meade (1987). Linn & Petersen (1985) suggested that spatial visualization presents less consistent pattern of sex differences. Boardman (1990) claimed that boys, as they grow older perform better then girls of the same age in drawing tasks and Maccoby & Jacklin (1974, in Liben, 2006, p. 208) agreed that sex related differences in spatial skills do not emerge until adolescence.

Frequent engagement with electronic games related to a better visualization of landscape with maps. However the difference was not statistically significant and our research hypothesis was not confirmed. A number of studies indicate that electronic games enhance learning (Chen & Michael, 2005; Cordova & Lepper, 1993). Further research should be conducted aiming at the investigation of the role of educational electronic games in learning with maps and how to translate learning objectives into gameplay with educational implementations. Anagnostou (2010) suggests that educators should experiment with simple electronic games applying concepts that support learning objectives and evaluating the results of using game-based learning in educational environments.

Naïve theories linking distance perception with the acquaintance of a place are still present at the age of 11. This implies that egocentric representations (Siegel, 1998) are not yet abandoned. The factor of acquaintance with a place is dominant in children's mental representations of the environment and the feeling of security that derives from using for example home as a reference point may lead to systematic distortions of spatial representations (Biel, 1982). A few pupils based their selections on prior visits to a city and familiarity with a place or incorporated explanations that are significant in their everyday lives, such as safety parameters or easier access by boat, showing inability to conceptualize relief with the use of a 3D map.

Some route depictions showed errors or distortions. The connecting route was interrupted either before the display of mountainous regions or at the edges of the word of the selected city. This relates to problems with symbology (DeLoache, 1989, Liben & Downs, 1992). A few pupils confused the point symbol of the city with the word of the city name. Teachers should clarify that the location of a city is represented by point symbols defined on the map legend and not by the word of the city name. Cartographers should also consider better placements of city names on maps, as they might produce confusion during map related tasks.

The following areas of further study can be suggested from this research. Firstly, even though the research sample was representative of the ratio of Greek urban and rural population, it is proposed that further investigation should be conducted in mountainous regions about children's landscape conceptualization and distance perception. The quality of environmental experience should be analyzed in more detail and correlated with pupils' performance in mapping activities. Everyday geographies of rural pupils with rich environmental experiences should be utilized in map reading activities. We agree with Martin (2008) that primary geography teachers should be aware of the distinction between everyday and academic geographies and comprehend how to enable connections between the two.

Educational resources and training are more easily accessible to teachers living in cities and that reflects on children's map reading abilities. Lifelong learning with the use of educational platforms, such as Moodle, could bridge the difference of educational opportunities between city and rural regions. We advocate that these new technologies will enhance geography and should be implemented in national or European networks. Such efforts have started in Greece in the field of environmental education for secondary teachers and should expand to primary teachers including map work in this context. 3D maps are a useful tool applied successfully in this research. Therefore further research should be conducted to investigate the use of 3D maps combined with GIS applications and navigation tools for the improvement of pupils' abilities to understand relief.

Acknowledgments

We would like to thank Professor N. Soulakellis (Laboratory of Cartography and Geoinformatics) for the provision of the maps utilized, Lecturer V. Gavalas for his suggestions on the statistical analysis of the results and all directors and teachers that collaborated.

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