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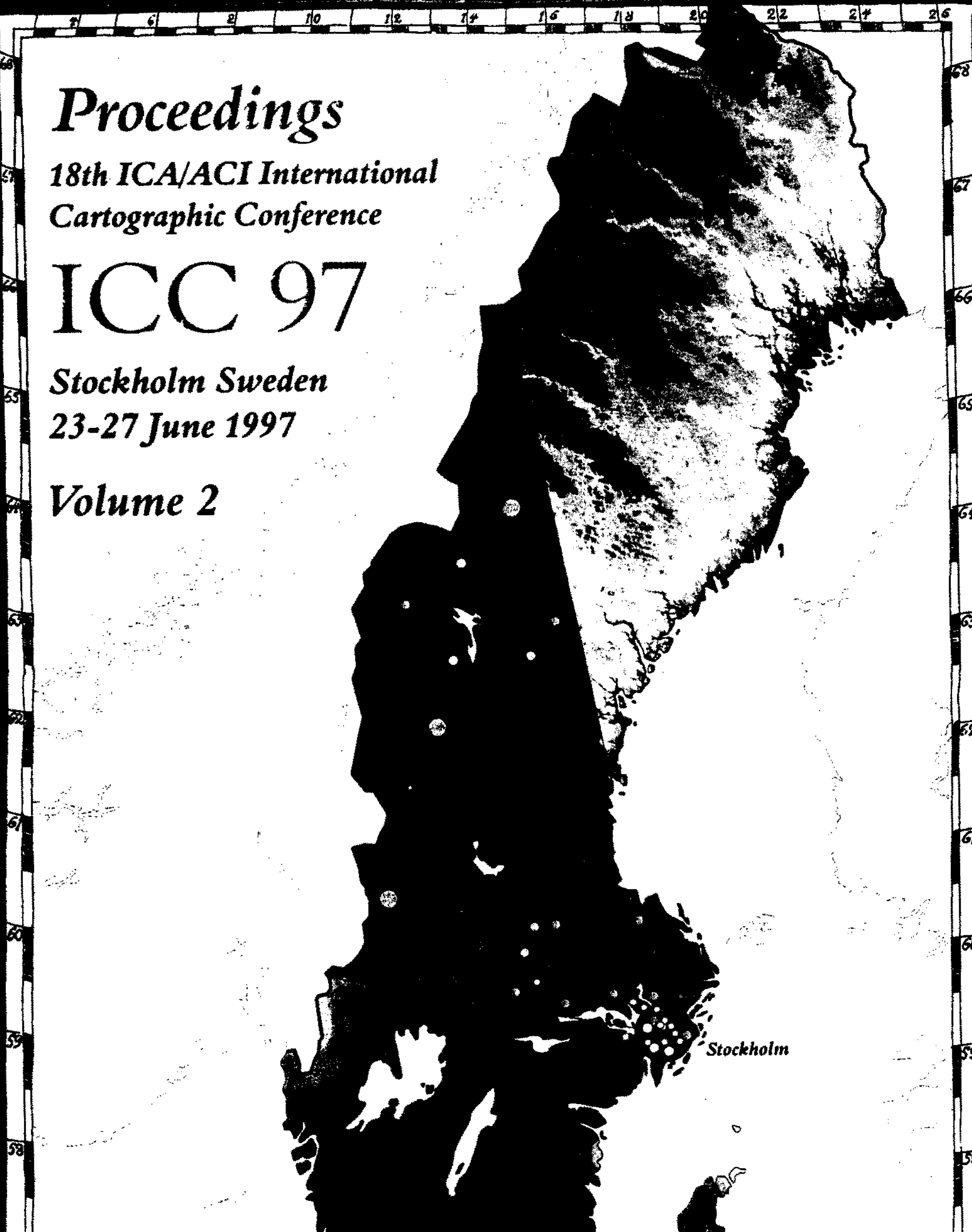


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# A STUDY ON THE ABILITY OF CHILDREN IN UNDERSTANDING THE FUNDAMENTAL ELEMENTS OF REALITY PRESENTED ON MAPS

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**Abstract**
This study examines the way school children perceive the fundamental elements of reality presented on maps, taking into account the spatial and cognitive developmental levels, the fundamental cartographic functions and the analytical curriculum. The research is based on a test addressed to elementary school children of Cyprus. The test material consists of different scale maps. The maps are specially designed to support basic cartographic functions, such as: spatial orientation, topological relationships, sorting and measuring objects, etc. The results reveal that the ability of children to perceive fundamental cartographic functions is gradually increasing.

## 1. Introduction

School maps are among the first perceptual images of the world for children, so that their study demands special care and attention. The creation of school maps is a rather difficult procedure since children cannot explicitly express their needs, so it has to be the result of research and study of a team of scientists specialized in education, children's psychology and cartography.

Any spatial information transmitted through maps, can be faced as an expression of portraying basic elements of reality. This idea is expressed by Robinson with the following statement: "All maps are concerned with two fundamental elements of reality: locations and attributes at locations" (Robinson *etal.*, 1984). Starting from the same idea, but focusing on a different aspect, the basic elements of reality portrayed on maps are defined, after an analysis of the basic functions of map reading. Based on the map information capacity and the limitations set by the clarity and legibility achievements, the maximum number of attributes presented at a location are determined and through them, the elementary functions of map reading are derived.

The way children react with maps has been the research topic of many cartographers in the last two decades. Many experimental studies with pre-school children have concluded that children are able to: i) identify features on aerial photographs (Blaut and Stea, 1971), ii) find a hidden toy indicated on a large scale map of a room (Bluenstein and Acredolo, 1979), iii) locate the position of an object using a large scale model of a room instead of a map (Blades and Spencer, 1986), iv) navigate on a predetermined path outline on a large scale map (Blades and Spencer, 1986; Freundschuh, 1990), v) identify and locate point, line and area symbols on pictorial and abstract maps (Anderson, 1994) and vi) understand many map and globe related concepts if such concepts are presented in suitable manner (Atkins, 1981). It can be concluded that children can be introduced to cartographic practice before going to elementary school, at the stage of pre-operational level (Piaget and Inhelder, 1967). Other studies working with children at the concrete operational level, 7÷12 years old, argue that: i) there is a sequence of development of children's competence in cartographic language, which is more evident in their comprehension of cartographic symbol than in their identification as the latter is acquired at an earlier stage (Gerber, 1983), ii) according to the same study the identification of quantitative line and qualitative area symbols and the comprehension of quantitative symbols, especially line symbols, are the most difficult process, iii) the interpretation of features on maps should follow the recognition of spatial relationships between real features; the maps should not contain too much detail (Ottoson, 1988). It is not yet clear what should be a «map» for elementary school children, should it differ from an adult map? That was a point of interest for the present research.

So, in this study the way school children react to map reading procedures is examined, taking into account the theory of spatial and cognitive developmental levels, the cartographic fundamental functions and the aims of analytical curriculum. The research is based on a test addressed to elementary school children of town of Limassol, Cyprus. The test material consists of different scale (large and small) paper maps, both general and thematic. The maps are specially designed (content and format) to test children's ability in reading adult maps and support basic cartographic functions, such as: spatial orientation, measuring distances, topological relationships, identifying objects, sorting and measuring objects, etc.

## 2. Theoretical concepts

### 2.1 Psychological aspect (children spatial abilities)

The analysis of the stages of cognitive development with special concern on spatial knowledge based on Piaget theory (Piaget and Inhelder, 1967) is well established in cartographic literature related to children (Robinson and Petchenik, 1976; Winn, 1987). A brief reference to children's spatial knowledge and a selection of some skills related to mapping activities that acquired by children until 12 years old according to Piaget theory are cited (Phillips, 1969; Dimitriou, 1993). Children perceive the simple topological relationships of proximity, separation, enclosure, order and continuity and also develop the idea of permanence in objects during the sensory motor period (0÷2 years).

The ability to manipulate symbols (words, images etc.) is the main feature that differentiates the children of pre-operational period (2÷7 years) from the children of the sensory motor period. Later in pre-operational period children can classify or order objects using only one attribute but do not truly comprehend concepts such as "some and all" or "smaller and bigger". By the age of seven or eight they have already acquired most of the projective relations which involve straight lines and perspective and some Euclidean relationships. Children of operational period (7÷11 years) among others, accomplish classification or ordering of objects using more than one attribute at a time and acquire the concepts of unit of measurement, of co-ordinate system etc. By the age of eleven or twelve, reaching at formal period, they develop the understanding of Euclidean space and are able to relate locations to one another simultaneously.

2.2 Basic cartographic functions

General maps as well as thematic are specially designed to support basic cartographic functions with the aim of transmitting spatial information that can be classified in geometric information and thematic information. Geometric information is extracted through: i) positioning of portrayed objects, ii) interpretation of their relative position, iii) measuring of distances-angles-bearings. Thematic information is extracted through interpretation of: i) qualitative and ii) quantitative characteristics of the geographical phenomena portrayed on the map. After cartographic manipulation, all geographical phenomena regardless of their dimensions (point-linear-area-volumetric), can be faced and consequently symbolized as points, lines or areas. The geometric information extracted from a map is actually the result of point determination, since both lines and areas in maps can be faced as sequences of points. Measurements of distances, angles and bearings are derived from the positioning of points. So, in the process of reading maps, point positioning (by means of plane co-ordinates) is the elementary function on which any geometric relation is based. The portrayal of the relief and all thematic information either qualitative or quantitative depicted on maps can be seen as attributes occurring at points, lines or areas, since all of them are faced as data that have to be symbolized and the recognition of attributes is the other elementary function in map reading. Considering the limitations set by the available space in order to attain through the graphical design the desirable clarity and legibility of the map, it comes out that at a certain point a limited number of attributes can be presented. More specifically, at a certain point of a map, there can be a point, a line and an area symbol portrayed. Only in extreme cases of thematic mapping there can be more than one line coinciding at a point and two area symbols covering the same area. Considering that the information about the relief is read through the contours it is concluded that the usual number of attributes portrayed at a point is three and the maximum is four. The existence of more than four attributes portrayed at a location, would cause confusion in the interpretation of the map.

## 3. Curriculum of Cyprus elementary schools

Formal study of maps begins at third grade eventhough pre-school children are capable of accomplishing some mapping activities. Students of first and second grade acquire geographical concepts for local and neighbouring environment from social studies and different skills like appreciate relative sizes, define topological relations, identify simple geometrical shapes, classify or order objects using one attribute and measure distances using mostly non conventional units, from mathematics.

Third grade students are supposed to face large scale maps of their environment, but such a material is not available, and small scale maps of Cyprus. Students are mostly encouraged to identify point, line and area symbols which present nominally scaled data, to interpret a legend and the conventional colour for area symbols. They locate different phenomena and determine relationships among locations. Children deare used for towns, black dot point symbol for villages, double red line for highways, single red line for secondary roads and black line for district boundaries. Rivers, lakes and the sea are in blue colour.

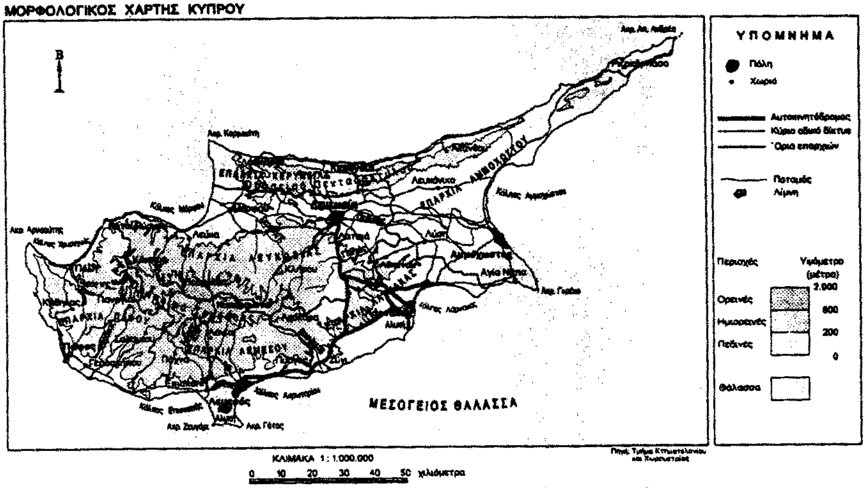


**Figure 1**. A small scale map used for the study.

ii) Political map of Cyprus. It includes all the information of the previous map except for the hypsometrical zones.
iii) Population map of Cyprus. The population size of towns or villages is portrayed by graded red circles. Hypsometrical zones are depicted by different values of yellow and district boundaries by black line symbol.
iv) Mean annual temperature map of Cyprus. Different temperature zones are portrayed by different values of orange starting with dark value for high temperature. Black point symbols of different size portray towns and villages.
v) Map of a part of Limassol (fig. 2). A colourful thematic map which includes, buildings, building blocks and plots, green area, sea, roads, pedestrianized streets, rivers, fountains etc. Pictorial point symbols are used to present different buildings and places like schools, tennis court etc.
vi) Land use map of a part of Limassol. On the background of the previous map different land uses like cultivation, building areas etc. are varying in hue.

Different features are labeled on each map. Numerical information is written in the legend representing quantitative data. Title, scale, north arrow, legend and the source of data are given.

## 4.3 Questionnaires

Six questionnaires corresponding to the maps were composed taking into account teachers' advice and examples of Geography tests for their format and vocabulary. Examples of the 40 questions included to evaluate children's ability in extracting the four kind of spatial relationships from a map, are cited here:

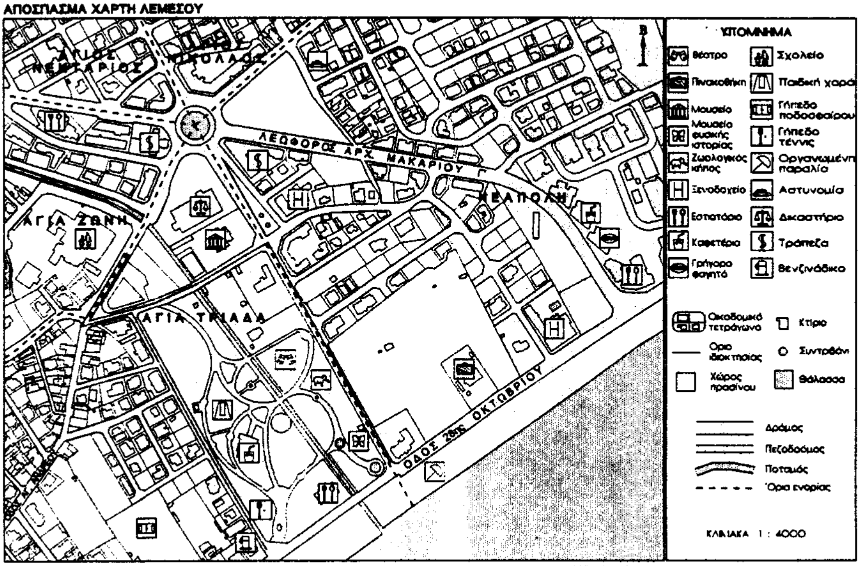


**Figure 2**. A large scale map used for the study.

i) $R_1$: ($P_1$-$P_2$) relationships among points: *which is the most distant town from Limassol; the court is located to the north, south, east or west of the museum.*
ii) $R_2$: $P_1(A_1,A_2,A_3)$ relationships among attributes at a point: *put a sign "X" at a hilly place in Nicosia district where a river is passing through; put in a circle the part of a pedestianized street which is located next to a river and a fountain.*
iii) $R_3$: $(P_1)A_1$-$(P_2)A_1$ spatial distribution of an attribute: *write down the towns of Cyprus according to an ascending order of population; write down from which land uses does the river pass through.*
iv) $R_4$: $P_1(A_1,A_2)$-$P_2(A_1,A_2)$ spatial distribution of two attributes: *write down the name of a mountainous village with population more than 500 inhabitants; put a sign "Z" on a restaurant which is located in a green area.*

### 4.4 Sample description

Four classes of each grade 3÷6 were randomly selected from two elementary schools one located in the center and the other at the periphery of Limassol. The population is approximately 7500 students and the sample consists of 437 students (more than 5%), 106 attending at each third, fourth and sixth grade and 119 at fifth grade. The age of the third grade students ranges from 7.8÷8.7 years, of the fourth grade students from 8.8÷9.7 etc.

## 5. Statistical analysis of the results

Statistical analysis was carried out using the statistical package SPSS for Windows. For each grade, the frequency and the associated percentage of students with scores or correct answers in each of the class intervals are listed in table 1. The scores distribution has a mean (M) of 58% standard error (SE) of ±2% and standard deviation (SD) of ±20%.

**Table 1**. Grouped frequency distribution.

| Grade | 3 | 4 | 5 | 6 | Total |
|---|---|---|---|---|---|
| 91÷100 | 0 (0%) | 0 (0%) | 5 (4%) | 19 (18%) | 24 (5%) |
| 81÷90 | 0 (0%) | 9 (9%) | 11 (9%) | 21 (20%) | 41 (10%) |
| 71÷80 | 3 (3%) | 20 (19%) | 30 (25%) | 34 (32%) | 87 (20%) |
| 61÷70 | 9 (8%) | 16 (15%) | 24 (20%) | 13 (12%) | 62 (14%) |
| 51÷60 | 18 (17%) | 16 (15%) | 16 (13%) | 7 (6%) | 57 (13%) |
| 41÷50 | 36 (34%) | 20 (19%) | 22 (19%) | 5 (5%) | 83 (19%) |
| 31÷40 | 15 (14%) | 12 (11%) | 7 (6%) | 4 (4%) | 38 (9%) |
| 21÷30 | 18 (17%) | 10 (9%) | 3 (3%) | 2 (2%) | 33 (8%) |
| 11÷20 | 6 (6%) | 2 (2%) | 1 (1%) | 1 (1%) | 10 (2%) |
| 0÷10 | 1 (1%) | 1 (1%) | 0 (0%) | 0 (0%) | 2 (0%) |
| Total | 106 | 106 | 119 | 106 | 437 |

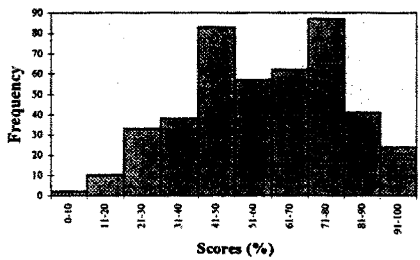


**Figure 3**. Frequency of total scores distribution histogram.

The percentages of correct responses for the 40 questions included in the questionnaires were used to calculate the mean number of scores for each grade. A one-way analysis of variance was performed which revealed a statistically significant effect for group, $F(3,433)=63.13$, $p<0.05$ (table 2). Sheffe' multiple comparison test was performed to determine which of the groups' differences are significantly different. The results of this analysis indicated that groups were significantly different from one another, ($p<0.05$). Group mean-scores significantly increased from grade three to six. Group means, standard errors and standard deviations in parenthesis are presented in table 3.

**Table 2**. Variance analysis for grade differences.

| Source | D.F. | Sum of Squares | Mean Squares | F Ratio | F Prob. (P) |
|---|---|---|---|---|---|
| Between Groups | 3 | 54250 | 18083 | 63.13 | 0.00 |
| Within Groups | 433 | 124025 | 286 | | |
| Total | 436 | 178275 | | | |

Students mean scores on perceiving $R_1$, $R_2$, $R_3$ and $R_4$ relationships from maps are represented by grade in table 3. The table indicates that: i) for all relationships the group means increase gradually from grade three to grade six, ii) the relationships have different grade of difficulty.

Table 3. Total results of the four relationships.

| Grade | $R_1$ | $R_2$ | $R_3$ | $R_4$ | Total |
|---|---|---|---|---|---|
| 3 | 52 ±2 (±15) | 35 ±3 (±30) | 26 ±2 (±22) | 36 ±2 (±22) | 43 ±1 (±14) |
| 4 | 66 ±2 (±19) | 40 ±3 (±29) | 42 ±2 (±26) | 45 ±3 (±30) | 55 ±2 (±18) |
| 5 | 69 ±2 (±17) | 49 ±3 (±28) | 50 ±2 (±22) | 53 ±2 (±28) | 61 ±1 (±16) |
| 6 | 83 ±2 (±18) | 57 ±3 (±30) | 64 ±2 (±25) | 67 ±2 (±25) | 74 ±2 (±17) |
| Total | 68 ±2 (±20) | 45 ±3 (±31) | 46 ±3 (±27) | 50 ±3 (±29) | 58 ±2 (±20) |

Students mean scores on small scale (upper indication) and large scale (lower indication) maps for $R_1$, $R_2$, $R_3$ and $R_4$ relationships are presented by grade on table 4. For each grade, the mean scores of each relationship on small and large scales maps were significantly different as indicated by paired t-tests at 0.05 level. The only exception refers to relationship $R_1$ of third grade. Generally, students performance is better on small scale maps rather that on large scale maps and the difference is increasing gradually by grade. Specifically, scores for relationships: $R_1$, $R_2$ and $R_3$ are higher on small scale maps and only score for relationship: $R_4$ is higher at large scale maps. Perceiving the spatial distribution of an attribute ($R_3$) on small scale maps appears to be simplest task whereas on large scale maps seems to be the most difficult task. In contrary, perceiving spatial distribution of two attributes ($R_4$) is easier on large scale maps. Extracting relationships among locations ($R_1$) is the easiest task on both small and large scale map.

Table 4. Total results of the four relationships in small/large scale maps.

| Grade | $R_1$ | $R_2$ | $R_3$ | $R_4$ | Total |
|---|---|---|---|---|---|
| 3 | 52 ±2 (±16) | 40 ±4 (±38) | 42 ±4 (±38) | 12 ±2 (±23) | 44 ±1 (±15) |
| | 52 ±2 (±23) | 30 ±4 (±36) | 9 ±2 (±19) | 59 ±3 (±35) | 42 ±2 (±18) |
| 4 | 68 ±2 (±21) | 49 ±4 (±36) | 70 ±4 (±38) | 36 ±3 (±35) | 62 ±2 (±21) |
| | 62 ±2 (±24) | 31 ±3 (±36) | 14 ±3 (±28) | 53 ±4 (±39) | 46 ±2 (±20) |
| 5 | 73 ±2 (±19) | 62 ±3 (±36) | 80 ±3 (±30) | 44 ±4 (±39) | 69 ±2 (±19) |
| | 62 ±2 (±21) | 36 ±3 (±38) | 21 ±3 (±29) | 62 ±3 (±33) | 50 ±2 (±18) |
| 6 | 84 ±2 (±17) | 66 ±4 (±38) | 87 ±3 (±28) | 62 ±4 (±40) | 80 ±2 (±18) |
| | 80 ±2 (±25) | 48 ±4 (±41) | 41 ±3 (±34) | 73 ±3 (±32) | 66 ±2 (±21) |
| Total | 69 ±1 (±22) | 54 ±2 (±38) | 70 ±2 (±37) | 39 ±2 (±39) | 64 ±1 (±22) |
| | 64 ±1 (±25) | 36 ±2 (±38) | 21 ±1 (±30) | 62 ±2 (±36) | 51 ±1 (±21) |

Table 5 reveals that students of each grade performed better in extracting relationships among locations ($R_1$) on political map rather than on physical. For each grade, paired t-tests indicated that the differences were statistically significant at 0.05 level. Generally, political maps include less information than the physical maps. This result agrees with other researchers who argue that maps addressed to children should not contain too much detail (Ottoson, 1988).

Table 6 reveals that students of each grade scored better in extracting information presented with symbols varying in ordinal scale rather than in numerical scale from the same map. For each grade, paired t-tests indicated that the differences were statistically significant at 0.05 level. This result extends other similar cartographic research about the ability of children to comprehend quantitative symbols from maps (Gerber, 1984).

**Table 5**. Results of physical vs. political map.

| Grade | PHYSICAL | POLITICAL |
|---|---|---|
| 3 | 46 ±2 (±20) | 58 ±2 (±21) |
| 4 | 62 ±2 (±24) | 73 ±2 (±26) |
| 5 | 66 ±2 (±25) | 80 ±2 (±21) |
| 6 | 80 ±2 (±18) | 89 ±2 (±21) |

**Table 6**. Results of symbols varying with ordinal vs. numerical scale.

| Grade | ORDINAL | NUMERICAL |
|---|---|---|
| 3 | 37 ±3 (±33) | 19 ±2 (±21) |
| 4 | 57 ±3 (±35) | 42 ±3 (±36) |
| 5 | 73 ±3 (±30) | 54 ±3 (±32) |
| 6 | 76 ±2 (±27) | 64 ±3 (±34) |

**Table 7**. Mean scores of boys vs. girls per grade.

| Grade | BOYS | GIRLS |
|---|---|---|
| 3 | 43 ±2 (±15) [55] | 42 ±2 (±14) [51] |
| 4 | 55 ±3 (±20) [60] | 55 ±2 (±17) [46] |
| 5 | 62 ±2 (±17) [67] | 62 ±2 (±16) [52] |
| 6 | 73 ±2 (±17) [54] | 74 ±2 (±18) [52] |

Table 7 represents the mean scores of boys and girls and the group size in brackets for each grade. An analysis of variance do not provide evidence of significant differences among boys and girls.

## 6. Conclusions

Allthough the answers to the questionnaires have been discussed following the tables with the results, some general conclusions have to be mentioned here, that can be considered in further discussion or future research. As it was expected, the scores in answering the questions are gradually increasing from the third to the sixth grade. Boys' and girls' reactions to the questionnaires are of the same level. An interesting point, is that children can read maps and perceive the fundamental elements of reality, even without having taught this procedure at school, as shown by the answers of the third grade's students. That leads to the idea of introducing map reading at earlier stages in school program. The recognition of quantitative thematic data is of importance, since the results reveal that students understand easier the ordinal scale portrayal than the numerical scale portrayal. Information conserning locating positions, topological relationships, comparison of distances, can be easier extracted from a political rather than a physical map. The last remarks can be taken in mind for designing maps of elementary school children.

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