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Pupils' representations of rivers on 2D and 3D maps

Ekaterini Apostolopoulou & Aikaterini Klonari*

University of the Aegean, Department of Geography, Mytilene 81100, Greece

Abstract

In this research we investigate the conceptions of 11 year old pupils about the flow of a river from its sources to the sea. 2D and 3D small scale maps were used from 287 pupils from 15 different schools situated in urban and rural environments from mountainous, plain and coastal areas of Greece. The purpose of the study was to investigate whether 3D maps contribute to a better understanding of a fluvial system on the physical landscape, to identify stereotypical imagery about the direction of the river flow, and to identify the type of map that will help children visualize and better understand features of the natural environment. Pupils completed an individual questionnaire with closed and open ended questions and designed rivers on 2D and 3D maps. The results were analyzed and categorized into model types according to the direction, the representation of the mouth of the river, the consistency of the river flow with the physical landscape, the types of lines used to draw the river's flow. A number of misconceptions are discussed. While the correct drawings on 2D maps surpass those on 3D maps, there is higher percentage of pupils drawing straight line river flow on 2D than on 3D maps suggesting that they cannot interpret the physical landscape through the map. Over two thirds of the pupils chose the 3D maps as more helpful to complete the task.

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Keywords:rivers; children's conceptions; 2D and 3D maps

1. Introduction

The Lucerne Declaration on Geographic Education for Sustainable Development has established a number of basic criteria when national curricula are developed, updated or assessed. One of the criteria for selecting geographic themes is: "Geographic perception of space, place and environment. Themes include the provision, use, evaluation, formation and meaning of space, place and environments" [1].

Maps serve as an important cognitive tool for the understanding of geographical space. They record and store information, they serve as computational aid, they facilitate mobility and way finding, they depict voluminous and complex data, they enable us to analyze, explain and predict trends, to visualize elements beyond our immediate experience, they stimulate thought [2].

Appreciating the significant role of maps in geographic education, the first chapter of the student's book in Geography in the 5th grade has as its title: "Maps. A tool for studying the world" [3]. In "Chapter B: The physical environment of Greece" they study "The rivers and lakes of Greece" aiming among others at identifying rivers on the map and distinguishing the features of a fluvial system [3].

In our research we hypothesized that the use of 3D maps would become an aid to the better understanding of landform and landscape, to the improvement of visualization and orientation skills. Therefore students would be facilitated to draw the flow of a river from its sources to the mouth according to the landscape. For that purpose we designed a questionnaire with 2D and 3D maps asking them to depict on the maps the watercourse.

* Corresponding author. Tel.: +30-225-103-6449; Fax: +30-225-103-6409
E-mail adresss:aklonari@geo.aegean.gr

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Previous research has investigated and categorized the levels of understanding of a hydrological concept of children aged 9-11 and their preferred river orientation [4], children's perceptions of river corridor environments and their views on restoring their rivers [5], children's perceptions and uses of river environments [6] and the use of 2D and 3D maps for the understanding of landscape [7].

The purpose of this study was to investigate whether 3D maps help upper primary school pupils to perceive efficiently the form and function of a fluvial system in accordance with the physical landscape. Students were asked to draw the flow of a river on 2D and 3D maps where the source of the river had already been identified for them. Our research questions focused on determining the level of understanding of the river flow on the physical landscape with the use of 2D and 3D maps, on identifying stereotypical imagery about the direction of the river flow, on investigating whether the pupils' preferences to a certain type of map as more helpful to complete the task, is followed by an efficient depiction of the river flow and on suggesting a type of map that will help children visualize and better understand elements of the natural environment.

2. Method

2.1. Participants

287 pupils from 15 different primary schools of the prefecture of Attica, Larissa and Lesvos participated in our study. 56% were located in inner-city areas, 25% in outer-urban areas and 19% in rural areas. 81% followed typical schools, while 19% followed single allocated staff schools. 51% were located in plain areas, 34% in coastal areas and 15% in mountainous areas.

2.2. Procedure

The research was conducted during the third trimester of the school year. Within an hour and under our supervision all students completed a questionnaire. It was mentioned that the scores would not affect their final grades. Permission was provided by the Pedagogical Institute and the Principal of each school.

The first part included questions on the educational background of the parents and the students' attitudes towards Geography. Then they were given colored 2D and 3D maps indicating the source of a river and were asked to design the watercourse. Finally pupils chose which type of map was more helpful for the design of the watercourse and justified their answers. Each student worked individually.

2.3. Materials

Children completed individually a questionnaire with the use of 2D and 3D maps. The maps were created at the Laboratory of Cartography and Geoinformatics of the University of the Aegean, Department of Geography. 3D maps were chosen from the educational software "Travelling to Greece".

2.4. Data Analysis

Data collections were conducted with the aid of printed questionnaires and were analyzed with the use of SPSS statistical package. The results were analyzed and categorized into groups of answers presented as following: orientation of flow, types of lines for the design of flow, depiction of mouth, correlation of depiction of flow and relief.

We searched for stereotypical depictions of rivers, for instance designs from left to right or from the top to the bottom of the page.

In addition we categorized students' representations in four mental models (scientific, non-scientific, proto-scientific and partly-scientific). We grouped pupils' preference to a certain type of map and compared their selection with the level of understating.

3. Results

3.1. Gender differences

For the orientation of the flow of the river with the use of 2D map 2% of the boys and 4.5% of the girls designed the flow of the river in accordance with the landscape. A greater number of students drew vertical lines from top to bottom (boys 18%, girls 15%), along the mountains (boys 15.7%, girls 13.8%) following the elevation curves (boys 7.7%, girls 4.5%). On the 3D map the number of children that drew the flow of the river following the landscape rises significantly (boys 30%, girls 28.6%). Others design the watercourse passing vertically the mountains (boys 10.8%, girls 11.8%). The stereotypical direction North-South decreases (boys 4.2%, girls 4.5%).

The types of lines used in 2D maps were straight lines (boys 8%, girls 8.4%), curves (boys 16%, girls 16%) and meandering lines (boys 20%, girls 16.3%). In the 3D maps the majority of both boys and girls used curves (boys 24.7%, girls 19.5%) and meandering lines (boys 12.2%, girls 12.9%). The number of boys the drew straight lines diminished (6.6%), while the number of girls increased girls (9.8%).

The majority of pupils did not draw a delta neither with the 2D maps (boys 45.6%, girls 40.4%) nor with the 3D maps (boys 46.3%, girls 41.8%). Boys used simple lines to depict the estuary (2D maps 19.1%, 3D maps 18.5%) and girls (2D maps14.3%, 3D maps 13.6%). They both similarly drew the estuary in the sea with the 2D maps (boys 18.1%, girls 19.1%) and with the 3D maps (boys 19.5%, girls 22.3%), while their lines stop before the coastline in greater frequency in 2D maps (boys 4.9%, girls 4.5%) then in 3D maps (boys 3.5%, girls 2.8%). Finally they drew almost on the same level the delta of the river in the 2D map (boys 3.5%, girls 3.1%) and the 3D map (boys 2.8%, girls 3.1%)

When questioned about which kind of map they perceived as more helpful for the drawing of the flow of the river the majority of boys and girls chose the 3D map (preference to 3D map boys 34.8%, girls 34.5%, 2D map boys 13.6%, girls 13.2%).

There is no statistical difference between boys and girls.

3.2. Design of river flow

Students drew the flow of a river with a given source on 2D and 3D maps. Correct designs with the use of 3D maps outnumbered correct designs with the use of 2D maps (2D maps 9.1%, 3D maps 52.6%). Straight line designs of the flow occurred less in 3D maps than in 2D maps (2D maps 18.1%, 3D maps 13.2%).

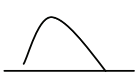
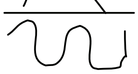
3.2.1. Orientation of river flow

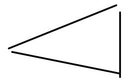
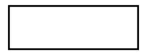
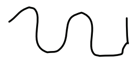
There are differences in the grouping of the orientation of the river flow in the drawings on the 2D vs. 3D maps. Orientation according to the landscape was identified on the 3D maps (58.9%) in opposition to the 2D maps (6.6%). Partly correct flow was drawn by students that designed the watercourse from a higher to a lower altitude but continuing on stable altitude (2D maps 8%, 3D maps 2.8%). Many pupils drew the flow following the axis North-South (2D maps 32.8%, 3D maps 8.7%). Misconceptions were identified on drawings of the flow along the mountain peaks (2D maps 29.3%, 3D maps 2.8%), flowing vertically through the mountains (3D maps 22.6%), along the elevation curves (2D maps 12.2%) following a course from one hill to the opposite hill (2D maps 8.4%, 3D maps 0.7%). Finally a small number of students did not start from the sources and followed a random course on both 2D and 3D maps (2D maps 0.3%, 3D maps 2.4%).

3.2.2. Line symbols for the depiction of river flow

Pupils designed the flow of the river with line segments (2D maps 16.4%, 3D maps 16.4%), curves (2D maps 32%, 3D maps 44.4%), meandering lines (2D maps 36.6%, 3D maps 25.1%), parallel lines (2D maps 3.1%, 3D maps 2.8%), rectangles (2D maps 1.4%, 3D maps 1.4%), triangles (2D maps 1%, 3D maps 0.3%) and meandering lines with arrows indicating the direction of the river mouth (2D maps 5.2%, 3D maps 5.2%).

Table 1. Line symbols for the depiction of river flow

Line symbols for the depiction of river flow		Percentage (%) 2D	3D
Line segments		16.4	16.4
Curves		32.0	44.4
Meandering lines		36.6	25.1
Parallel lines		3.1	2.8

Triangles		1.0	0.3
Rectangles		1.4	1.4
Meandering lines with arrow indicating the direction of the river mouth		2.5	5.2

3.2.3. Depiction of estuary

The majority of the pupils did not design a delta (2D maps 83.2%, 3D maps 83.7%). They designed the mouth using simple lines (2D maps 33.4%, 3D maps 32.1%), with delta (2D maps 6.6%, 3D maps 5.9%), with delta flowing into the sea (2D maps 4.9%, 3D maps 4.9%), simple line in the sea (2D maps 37.3%, 3D maps 41.8%), mouth before the coastline (2D maps 9.4%, 3D maps 6.3%), line ending in a point in the sea (2D maps 3.1%, 3D maps 3.5%) and line branching off in the middle of the root (2D maps 2.8%, 3D maps 4.5%).

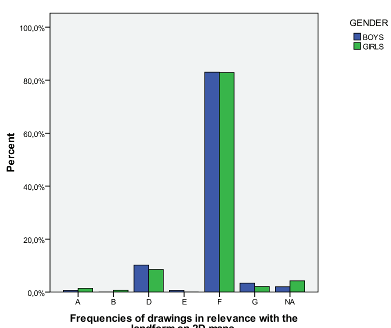
3.2.4. River flow drawings in relevance with physical landscape

The pupils' designs were grouped into seven categories describing the flow of the river from the source to the estuary in accordance with the landscape (Table 1).

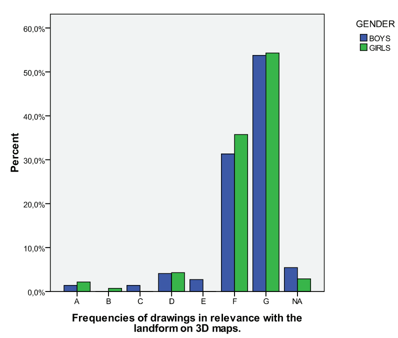
A majority of the drawings on the 2D map indicated where the river started and finished, but did not follow the landscape (82.9%), while the equivalent frequency on the 3D map is lower (33.4%). Rivers starting from the springs, finishing at the sea and following the landscape is outnumbered on the 3D map (54%) , see Table 2 and Fig. 1(a) and (b).

Table 2. Categories of drawings in relevance with physical landform.

Design prototypes	Frequency (%)	
	2D	3D
A. River does not start from springs, does not finish in the sea, does not follow the landscape	1.0	1.7
B. River does not start from springs, finishes in the sea, does not follow the landscape	0.3	0.3
C. River does not start from springs, does not finish in the sea, follows the landscape	0.0	0.7
D. River starts from springs, does not finish in the sea, does not follow the landscape	9.4	4.2
E. River starts from springs, does not finish in the sea, follows the landscape	0.3	1.4
F. River starts from springs, finishes in the sea, does not follow the landscape	82.9	33.4
G. River starts from springs, finishes in the sea, follows the landscape	2.8	54.0



(a)



(b)

Fig. 1. Frequencies of drawings in relevance with the landform on 2D maps (a) and on 3D maps (b).

3.3. Selection of map types

Pupils drew the flow of a river with a given source on 2D and 3D maps. Correct designs with the use of 3D maps outnumbered correct designs with the use of 2D maps (2D maps 9.1%, 3D maps 52.6%). Straight line designs of the flow occurred less in 3D maps than in 2D maps (2D maps 18.1%, 3D maps 13.2%).

3.3.1. Preferences between 2D and 3D maps

The majority of the students preferred the 3D maps to depict the course of the river's flow where the source had been identified on the map (2D maps 26.8%, 3D maps 69.3%, none 0,3%, both 1.4%). These results were correlated with the correctness of their drawings and are presented in Fig. 2.

Most students who drew correct sketches selected the 3D map (42.9%). Significantly, a large number of students also chose the 3D map even though they had wrong designs in both 2D and 3D maps. 2D maps were selected by a small number of students. (wrong design 2D and 3D maps 16.7%, 3D correct design 8.7%).

3.4. Mental representations

3.4.1. Explanations

Children were asked to explain why they had chosen a certain type of map as more helpful for the fulfillment of the task. Their explanations are displayed on Table 3.

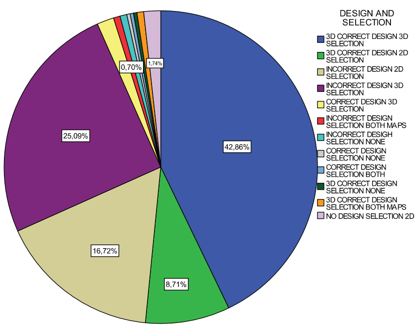


Fig. 2. Map selection related to depiction efficiency

Table 3. Children's explanations on selecting a map type.

Explanations	Percent (%)
It shows the image bigger	6.6
It is 3D	2.4
I understand better the map	14.3
Closer to the sea	19.2
It seems better to me	5.2
It has less rocks	1.7
It's easier	19.5
It shows the mountains better	23.3
It has more plains	3.5
None	0.7
No answer	3.5

The selection of a map type is influenced by the level of understanding of the features of the map. In other words, pupils consider more helpful the map that "shows better" a series of geomorphologic features (i.e. mountains, plains etc) (23.3%). The second most commonly occurring explanation was the close distance from the sea (19.2%). Some pupils explained their selection with the statement "I understand the map better" (14.3%) without specifying which elements are more helpful. Finally one rising misconception was the association of the map dimensions with its scale. As a result they selected the map with larger dimensions but not bigger scale (6.6%).

3.4.2. Levels of understanding of the flow of a river

The explanations pupils forwarded in favor of a certain type of map was compared with their drawings and resulted in the formation of four mental models:

A. Scientific model: drawings indicated where the river started and ended. The flow of the river followed the landscape and flowed into the correct bay. Pupils explained their selection using elements of the landform.

B. Partly – scientific model

i. Drawing indicated the springs and the mouth of the river. Explanations were referred to "the easiest path" without identifying geographic features or using geographic terms.

ii. Drawing indicated the springs and the mouth of the river. The selection was based on the dimensions of the map and not the scale. That is pupils identified geographic features, but stated that they "saw them better", "bigger" on the 3D map while in fact the 3D map has greater dimensions but smaller scale then the 2D map.

iii.a. The flow of the river did not follow the landscape, but pupils identified and described a number of geographical features (mountains, gorges, etc.) in their explanations.

iii.b. The flow of the river did not follow the landscape. The explanations were oriented towards the affordances of rivers for children [6]. The pupils used geographic terms, but their explanations were dominated by what the environment offers or provides ("There are plains that the river make fertile").

C. Non scientific model

i.a. The flow of the river followed the landscape, but pupils' selection was influenced by the distance of the indicated spring of the river until the shore (It's closer to the sea).

i.b. The flow of the river did not follow the landscape. Pupils' selection was influenced by the distance of the indicated source of the river until the shore (It's closer to the sea).

ii.a. The flow of the river followed the landscape. The pupils failed to explain their selection using geographic terms. They did not describe any geographic features. The most common answer was "it seemed to me better" or no explanation at all.

ii.b. The flow of the river did not follow the landscape. The pupils failed to explain their selection using geographic terms. They did not describe any geographic features. The most common answer was "it seemed to me better" or no explanation at all.

The mental models identified in the students drawings and explanations are presented in Fig. 3 and Table 4.

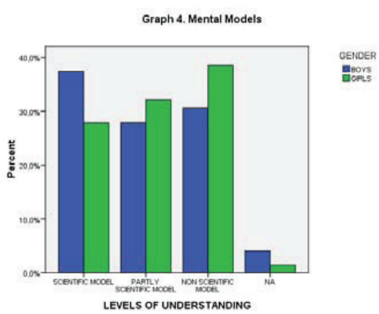


Fig. 3. Levels of understanding

Table 4. Mental models

Levels of understanding	Percent (%)
Scientific model	32.8
Partly scientific model	30.0
Non scientific model	34.5
NA	2.8
Total	100.0

4. Conclusions

Spatial thinking is a key organizing principle for geography education according to S. Bednarz, R. Bednarz and S. Metoyer (2009) [8]. Maps are an essential tool facilitating spatial visualization and reasoning. We argue that 3D maps influence children positively towards formulating and expressing scientific models.

The findings from this research suggest that pupils who drew on the 3D map the flow of the river according to the landscape have chosen the 3D map as more helpful for the completion of the task. These results indicate that the use of 3D maps contribute to a better understanding of landscape and are regarded as more realistic representations of the natural environment. These findings are in accordance with our previous research [7].

However, stereotypical imaginary is identified in our study. One third of the children followed the axis North-South in their drawings on the 2D map, while this percentage drops at 8.3 % with the use of the 3D map. This preference has been reported in other studies [9], [4].

From the perspective of gender differences in spatial skill we have not identified significant differences. Our findings align with previous studies that suggest that sex-related differences in spatial skills do not emerge until adolescence and that spatial visualization present a less consistent pattern of sex differences [10].

We agree with Mackintosh (2005) [11] that "children should be encouraged to visualize rivers and be enabled to develop three dimensional mental constructions of rivers (p. 321) and we advocate that 3D maps can be an effective vehicle to gain a more accurate cognitive image of our natural environment especially in the case of urban children with less opportunities to experience outdoor activities close to actual rivers. Primary geography should therefore introduce the use of 3D maps in the curricula for the development of spatial thinking.

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