www.rigeo.org ISSN: 2146-0353
RIGEO
Review of International Geographical Education Online

Review of International Geographical Education Online ©RIGEO Volume 9, Number 2, Summer 2019

Research Article **Copyright © RIGEO 2019**

To cite this article: Klonari, A.; Styliani Passadelli, A. (2019). Differences between dyslexic and non-dyslexic students in the performance of spatial and geographical thinking. *Review of International Geographical Education Online (RIGEO)*, *9*(2), 284-303. Retrieved from http://www.rigeo.org/vol9no2/Number2Summer/RIGEO-V9-N2-2.pdf,

DOI: 10.33403/rigeo.510360

Submitted: January 9, 2019 **Revised:** July 5, 2019 **Accepted:** 24 July 2019

Differences between Dyslexic and Non-Dyslexic Students in the Performance of Spatial and Geographical Thinking

Aikaterini KLONARI[1]
University of the Aegean, Mytilene, GREECE

Anthoula STYLIANI PASSADELLI[2]
University of the Aegean, Mytilene, GREECE

Abstract

Dyslexia is a specific form of learning disability which comes along with diverse difficulties, both in learning, social and emotional fields. It obstructs the development of the individual at all levels of education. This research investigates students' spatial and geographical thinking and whether there is a differentiation of these abilities between dyslexic and non-dyslexic ones. For this purpose, 50 questionnaires were distributed to 25 dyslexic and 25 non-dyslexic students aged 14 using opportunity sampling from different areas (rural, urban). The questionnaire included spatial thinking exercises like mental rotation, plan views, shapes folding - unfolding and mental manipulation of shapes and exercises by which geographical thinking is examined, according to the Greek geography curriculum. The results indicated that the non-dyslexic students had better performance than the dyslexic ones in all cases, except one, this of 2D ◄► 3D exercise. The most significant difference was in the section of plan views, mental rotation and folding - unfolding, whereas in the shapes mental manipulation, both children's groups faced difficulties. Although the research sample was limited, the results supported our hypothesis that non-dyslexic students would perform better on spatial and geographical thinking assessments.

Keywords

Spatial Thinking; Geography Performance; Dyslexic Students; Secondary Education

[1]Prof. Aikaterini Klonari, University of the Aegean, School of Social Science, Department of Geography, University Hill, Mytilene, Lesvos, Greece, E-mail: aklonari [at] geo.aegean.gr
[2]PhD Candidate Anthoula Styliani Passadelli, University of the Aegean, School of Social Science, Department of Geography, University Hill, Mytilene, Lesvos, Greece, E-mail: geod17002 [at] geo.aegean.gr

Dyslexia is a learning disability that concerns teachers, parents and special scientists. It is one of several distinct learning disabilities which affect various areas of academic performance. Dyslexia is one of the most thoroughly studied types of learning disabilities, affecting more than 80% of all individuals identified as learning disabled (Meisinger et al., 2010; Melekoglou, 2011; Tafti et al., 2014). It is connected to learning disabilities in reading, writing and sequenced symbolic information (Powell et al., 2015). This specific reading disability affects approximately 4-10% of the school age population (Aleci et al., 2012; Kotsopoulos et al., 2017; Bacon et al., 2007). The following definition captures the essence of the issue: "Dyslexia is a neurologically-based, often familial disorder which interferes with the acquisition of language. Varying in degrees of severity, it is manifested by difficulties in receptive and expressive language, including phonological processing, in reading, writing, spelling, handwriting and sometimes arithmetic. Dyslexia is not the result of lack of motivation, sensory impairment, inadequate instructional or environmental opportunities, but may occur together with these conditions. Although dyslexia is life-long, individuals with dyslexia frequently respond successfully to timely and appropriate intervention" (Orton Dyslexia Society, 1994).

In the past many researchers believed that dyslexia is created by four causes: Perceptual deficits (Zoccolotti, de Jong, Spinelli, 2016), memory deficits (Liberman et al., 1982; Jorn, 1983), language processing deficits (Rozin & Gleitman, 1977; Marsh et al., 1981), and visual processing deficits (Lovegrove et al., 1982; Livingstone et al., 1991). These specific deficits may be isolated, the “simple” deficit case, or come together, the “multiple” deficit case. Dyslexic persons, depending on the nature of their difficulties, fall into one of the following categories: visual dyslexia and auditory dyslexia (Reid, 2008). Many times, depending on the form of the problem, there is a combination of these two, this is known as mixed dyslexia. Visual dyslexia is a widespread form of dyslexia and it creates serious problems with reading, confusion in sequencing, difficulty in ordering a sequence of instructions from parents or from the teacher. One major feature of visual spatial dyslexia is the inability to orient in space. Therefore, dyslexic individuals have topographical disorders (topographical disorientation), e.g. extreme difficulty distinguishing right from left, top from down and following a sequence of directions or retracing a path, may be related to difficulty remembering sequences and short term memory deficits, or difficulties decoding symbols and reading a map (Wong, 1998; Brunsdon, Nickels, & Coltheart, 2007; Bekiari & Simitzi, 2012; Orphanou, 2013). The youngest children face significant problems with the spatial relationship around them, where they are characterized by clumsiness and difficulty in moving inside the home. These difficulties evolve over time and in puberty show up as difficulties in spatial thinking or inability to understand a layout or a conceptual map (Tzelepi-Giannatou, 2008). Lerner (2011) indicated that Perception Spatial Relations Disabilities is one of the manifestations of learning difficulties represented by children's failure to recognize spatial relationships such as top and bottom, above and below, near and far, and in front of and behind. Furthermore, these children may appear to have difficulties in estimating the distance between numbers, difficulties in writing in a straight line, and difficulties in recognizing the sequence of numbers (Khasawneh, 2012). According to Sisanidou (1989), the perception of spatial relationships influences the pupil's performance in reading, writing and mathematics and in the perception of distance, scale, and interpretation of a plan view. The weaknesses of dyslexic students in the spatial-temporal orientation are:

- disturbances in the direction of space,
- confusing left to right, and yesterday to tomorrow,
- difficulty in learning time,
- difficulty in locating north and south on a map.

In order for persons to understand the concept of space, spatial representations and to be able to manage (critical thinking) the space, they must have spatial skills (NRC, 2006). A spatial skill is usually defined as spatial perception, visual representation and orientation in space. It is considered as a narrower concept than spatial thinking. So, the person communicates when he/she has spatial skills. This communication is defined as "spatial literacy" and refers to all abilities mainly in workplaces that aim to comprehend maps, images and spatial data, in the same way as the understanding of numbers, texts and logic are taught (Goodchild, 2006).

On the other hand, spatial thinking is considered a constructive ability that consists of three components:

- the concept of space,
- the tools of its imaging
- procedures of understanding and analysis.

Bishop (1980) suggested spatial thinking as one of the most important skills that humans have developed to achieve the best adaptation to their environment. Spatial thinking allows people to use space to model the world (real and theoretical), structure problems, find answers, express and communicate solutions. The inclusion of concepts of space makes spatial thinking unique from other types of thinking (NRC, 2006). Lee & Bednarz (2009) had the same view stating that spatial thinking is associated with real life, with the most effective handling of actual situations. Spatial thinking can be defined as a constructive combination of cognitive skills comprised of knowing concepts of space, using tools of representation, and applying processes of reasoning (NRC, 2006). Hespanha et al. (2009) had explained: "Learning to think spatially means that we should have knowledge of spatial concepts, we can think and act in space and know how, where and when to use different strategies, appropriate tools and technologies to solve problems or make decisions on matters related". Location, scale, pattern, spatial association, analogy, network, and proximity are examples of spatial concepts that have been explicitly recognized by researchers (Gersmehl & Gersmehl, 2006; 2007; Golledge, 2002; Janelle & Goodchild, 2009). Moreover, tools of representation such as maps, graphs, sketches, diagrams, images, and models enable and support spatial thinking. Spatial thinking often necessitates complex reasoning (Jo & Bednarz, 2009). Gersmehl & Gersmehl (2007) define spatial thinking as the skills which geographers use to analyze spatial relationships in the world.

In addition, geography is a science that studies the relationship that develops between the Earth System (place, space and environment) and humans. Moreover, it is the science that enables us to understand the Earth in which we are living from a spatial perspective. Undoubtedly, many things in peoples' daily life are interwoven with geography and of course geographic knowledge enables people to understand things they do and how every day actions affect the world around them (Klonari & Passadelli, 2016). For this reason and as a predominantly spatial science, it is directly connected with the development of the student's spatial thinking and the cultivation of spatial abilities (Klonari & Kotsanis, 2015). Geography in secondary education aims at developing an understanding of the geographical area, interpretation of interactions between natural phenomena and between each person and the environment. Recently, increased interest in geographic education has been shown, both at Greek and international levels, particularly in developing the quality of geographic education in content and teaching methods, as well as curricula (Bettis, 2001; Klonari, 2004; Brooks, 2006; Klonari & Mandrikas, 2014). In order to achieve the desired learning outcomes, we will have to implement interesting and innovative teaching methods, train teachers and have fruitful school environment (Klonari, 2012).

We are wondering whether special learning difficulties, such as dyslexia hinder the development of geographic knowledge and spatial thinking. How are dyslexic students able to develop spatial thinking? Research studies offer opposing views. Giovanioli et al. (2016) argue that children with dyslexia have deficits in several spatial abilities. This is in contrast to the point of view that the individuals with dyslexia have superior spatial processing ability (Duranovic et al., 2015; Wang & Yang, 2011; Bacon et al., 2010). Aleci et al. (2012) found that there is no evidence for enhanced spatial orientation ability in individuals with dyslexia. Giovanioli et al. (2016) have the opposite view and they found that children with dyslexia performed significantly worse than normal children in a mental rotation task. Also, there are researchers who argue dyslexic students are superior in other categories of tests. Furthermore, dyslexic students can distinguish 3D figures more quickly than normal students without higher error rates (Wang & Yang, 2011; Brunswick et al., 2010). The individuals with dyslexia have superior visual- spatial processing ability (Duranovic et al., 2015; Wang & Yang, 2011; Bacon et al., 2007). Aleci et al. (2012) found that there is no evidence for enhanced spatial orientation ability in individuals with dyslexia.

At this point, there is a discussion about how to develop spatial and geographical thinking in all students in general (researches have shown that they are at a low level) and dyslexics in particular need more learning support, while Geography is undergoing a crisis and it is a teaching subject that is neglected at school in recent years (Cohen, 1988; Kirchberg, 2000; Lam & Lai, 2003; Alim, 2009; Gokce, 2009; Jan-Bent et al., 2014; Schee, 2014).

In addition, due to the limited researches that have been conducted on this topic in Greece, the data of such a survey could help in the improvement of students' performance (specially dyslexic ones) and help teachers to consider not only what they teach, but also to whom they teach (Koutselini, 2008), creating appropriate teaching material to support the course of Geography.

Methodology

Rational and Research Limitations

This study addresses issues in the differences between dyslexic and non-dyslexic students in spatial and geographical thinking. This topic is important because in all Geography curricula and reform movements in the teaching of Geography, the emphasis is placed on the importance that geographic knowledge and skills (geographic literacy) have in preparing students to become informed and active citizens. Although there are many articles dealing with the school performance of dyslexic students, in a 12-year review, there are very few studies dealing with geographic literacy and geospatial skills of dyslexic students (Passadelli & Klonari, 2018). Surveys focus on childhood rather than adolescence (Faggela- Lubby & Deshler, 2008). Few researches refer to secondary education students and most of the studies deal mainly with writing problems and counting. Furthermore, researchers (Faggela- Lubby & Deshler, 2008) argued that there is lack of activities related to geography, particularly in the context of inclusive teaching, for students with these “special learning abilities”.

This research sample is not a representative one, but rather a small sample of convenience (Cohen, 2018). Consequently, it is not possible to generalize the findings of this research. It should also be noted that a characteristic of many students and especially of dyslexics is that they are easily tired and that their attention is also easily disrupted. This means that there is a chance that the questions will be answered randomly, so that students finish quickly. All the above could be limitations of this research, but the findings may be considered as indicative and trigger further and representative research.

Research Questions

The aim of the research is to investigate whether there are differences in spatial and geographical thinking between dyslexic and non-dyslexic students. Moreover, through the participants’ answers, researchers will find out the connection between the developments of spatial thinking with the teaching of geography.

The research questions raised in this research are:

- Do students with dyslexia have the ability to fully understand space by decoding its representation through maps, photos, etc.?
- Is there a difference in geography learning outcomes between dyslexic and non-dyslexic students?

Participants

The survey had been carried out in secondary public schools on Lesvos Island, Greece, in 2017. These schools belonged to urban and rural areas. A sample of 50 junior high school students participated in this, aged between 13-14 years old, 25 of whose were dyslexic and 25 non-dyslexic. The dyslexic students had been diagnosed with developmental dyslexia by professional psychologists and special educators in accordance with the diagnostic criteria based on the Greek Test of Specific Learning Difficulties in Reading and Writing. Both groups consist of an equal number of boys and girls (16 boys and 9 girls, respectively). The sample of non-dyslexic students were randomly chosen from the same schools and classes, to be comparable to the dyslexic one. The parents of 25 students were university graduates, the parents of 19 students were secondary school graduates and the parents of 6 students were primary school graduates. Also, 18/25 (72%) dyslexic students and 20/25 (80%) non-dyslexic stated that they like the lesson of geography and 22/25 (88%) dyslexic students and 21/25 (84%) non-dyslexic students think that they know how to handle computers very well. This research is a pilot survey in a specific region of Greece and is the beginning of a research project designed to be nationwide and based on cluster random sampling.

Survey Instrument

This study employed questionnaires to examine Greek students' dyslexic and no-dyslexic spatial and geographical thinking. The questionnaire was made up of three parts:

- First part – Demographic data: 17 questions about the students' personal data.
- Second part - Spatial thinking test: 20 questions with 36 items about the students' spatial thinking (with 36 possible points) (Newton & Bristoll, 2009; Tsaousis, 2008).
  - *Plan views:* focuses to recognize plans from above on a map or other visual display (6 questions* 2 items/12 points)
  - *Mental rotations:* (5 questions*3 items/15 points)
  - *Folding- Unfolding:* (5 questions/5 points)
  - *Mental manipulation of shapes:* (4 questions/4 points)
- Third part - Geographical thinking test: 10 questions about the students' geographical abilities/geospatial thinking (with 36 possible points) (Gersmehl & Gersmehl, 2007).
  - *Region*: is a group of adjacent locations that have similar conditions or connections (2 questions)
  - *Describing a Location:* focuses on determining the location based on the cardinal points or some other point reference (2 questions)
  - *Spatial Comparison:* is a tendency for two things to occur together, in the same places (2 questions)
  - *Spatial Analogy*: are places that may be far apart but have locations that are similar, and therefore they may have other conditions and/or connections that also are similar (2 questions)
  - *2D⬌3D:* focuses on identifying the arrow on a map that indicates where and which direction they are facing the view of the picture above and vice versa (2 questions).

These categories were chosen by the authors because they wanted to examine the relationships between spatial and geographical thinking. Each test item was designed to measure one component of spatial thinking identified by other studies (Gersmehl & Gersmehl, 2007; 2011; Lee & Bednarz, 2012).

Findings

For the research on Lesvos, we contacted the Geography teachers in schools and asked for their help in conducting the survey. We sent copies of the questionnaires and they were distributed to students by their teachers. The students filled out the questionnaire at school once parental consent had been received. After completing the questionnaires, the teachers sent them back to the researchers. Participation was voluntary, the responses were anonymous, and the time required to complete the questionnaire was about 50 minutes. The questionnaires were coded and scored by the authors. The scores were calculated for each category and quantitative analyses with descriptive statistics was used to examine the participants' abilities. Closed type questions were used in the category of spatial thinking, but in those questions where there were subquestions these were graded with one point for each correct answer. In the category of geographical thinking, the questions did not have subquestions but were open questions and each correct question was graded with 3.6 points. Each category was rated 36 points overall. The highest score that each group of students, in each part of the questionnaire, could collect was 900 points (25*36=900). Participants' gender, grades in Geography at school, place of residence and of course the group they belonged to (dyslexic or no-dyslexic students) were factors of comparison. The data were coded and analyzed using SPSSv 23.0. To measure the internal consistency of the test, the Cronbach's alpha was calculated after scoring all the tests which yielded a result of 0.653. There were correlations with gender, the parents' educational level and the grade in the geography lesson were not statistically significant. The analysis of the results of each category of questions is presented below. In all correlations we used one way ANOVA test because our sample is parametric.

Findings from Students' Answers in Each Category from the Second and Third Part of the Questionnaire

The second part. (Red letter indicates the correct answer)

Plan views. Significant problems have been identified in this type of exercises (Fig. 1). Non-dyslexics got 222 points and the dyslexics 152 points, respectively. It has to be noted that in these exercises the max points were 300 (25*12=300), for each group. The results indicated that there was a significant difference (F=10.777, p 0.002) between non-dyslexic and dyslexic students. The low scores lead us to the conclusion that all students' abilities are not satisfactory in this category "Plan views".

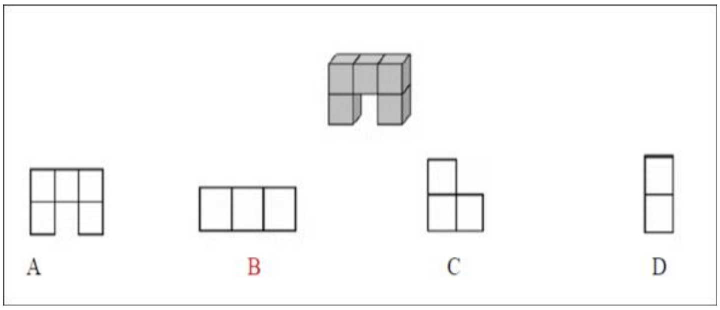


Figure 1. Example of plan view exercises: "Which 2D drawings is the top view of the 3D object?"

Mental rotation. As mentioned above, the analysis of the results was done with SPSS v.23.0. In mental rotation exercises (Fig. 2), the average score received by non-dyslexic students was 255 points (while max was 25*15=375) and dyslexics' was 117 (out of 375 max). The results indicated that there was a significant difference (F=36.171, p 0.000), between non- dyslexic and dyslexic students. So we observed that the problem faced by dyslexic students at mental rotation is obvious.

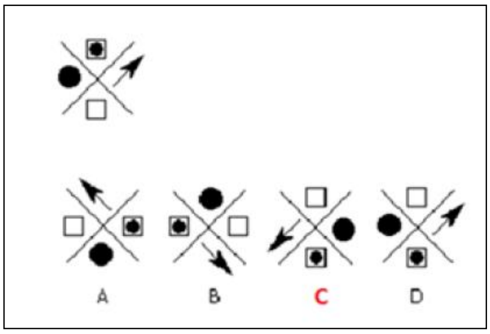


Figure 2. Example of mental rotation exercise: "Which figure is identical to the above?"

Folding-unfolding. In this type of exercises (Fig. 3), there were significant differences in the score. The non-dyslexics collected 102 (out of 25*5=125 max) of the correct answers and the dyslexics got only 35 (out of 125 max). The results indicated that there was a significant difference (F=27.016, p 0.001), between non- dyslexic and dyslexic students. So, we observed that the problem faced by dyslexic students at folding - unfolding is, also, obvious.

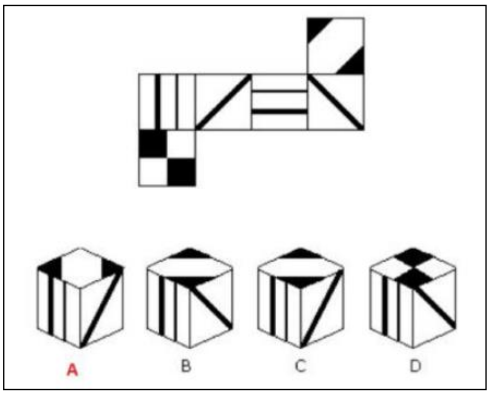


Figure 3. Example of folding- unfolding exercises: "Which of the cubes shown could be made from the above pattern?"

Mental manipulation of shapes. In this exercise (Fig. 4) the non-dyslexic gathered 98 and the dyslexics had 26 (out of 25*4=100 max, for each group). The inferential analysis (F= 10.086, p 0.22) suggested that there was no significant difference between the two groups. This exercise category seemed to be more difficult than all the others for all students.

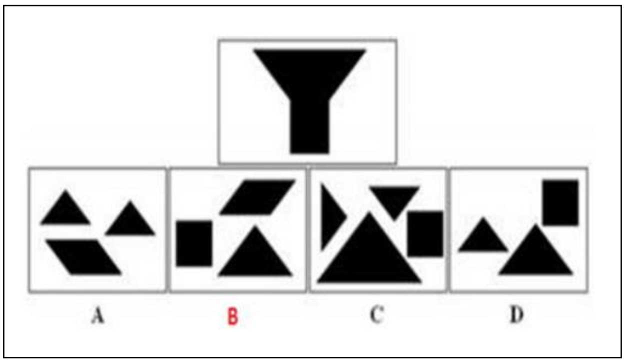


Figure 4. Example of mental manipulation of shapes exercises: "Which group of shapes can be assembled to make the shape shown?"

Total score in spatial thinking. The score obtained by non-dyslexic students in all exercises was 621 and the dyslexics scored 424, though the maximum score in all exercises of the second part of each group was 900 points. The result of the analysis indicates that there was a significant difference between two groups (F= 12.489, p 0.003). The results of this second part (spatial thinking) show that the performance of dyslexic students is low (Table 1), and they do not agree with their cognitive level. However, the normal degree of intelligence enables the teacher to intervene and achieve better learning outcomes because "how effectively one learns is determined by the use of appropriate cognitive and metacognitive strategies" (National Research Council, 2000).

Table 1
The score of dyslexic and non-dyslexic students in spatial thinking

	Dyslexics	**SD**	**Non-Dyslexics**	**SD**	**Maximum points**
Plan views	152	0.47	222	0.78	300
Mental rotation	117	0.35	255	0.80	375
Folding- Unfolding	35	0.22	102	0.58	125
Mental Manipulation of shapes	26	0.16	98	0.41	100
Total score in spatial thinking	330	0.89	677	0.99	900

Table 2
The significance of each correlation in spatial thinking test

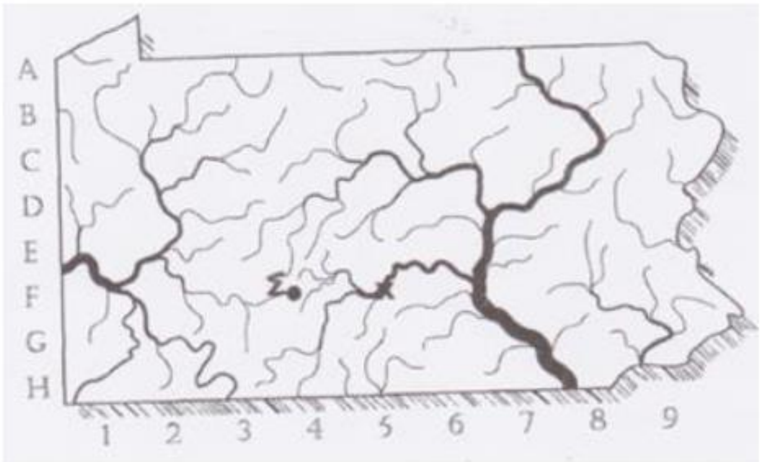
Categories of exercises	DF	F	P
Plan views	1	10.777	0.002
Mental rotations	1	36.171	0.000
Folding Unfolding	1	27.016	0.001
Mental manipulation of shapes	3	10.086	0.22
Total score in spatial thinking	1	12.489	0.003

Third part.

Region (Spatial groups). In this category (Fig. 5), no great difference was observed between the two groups, non-dyslexic students prevailed with a very small difference. Their scores were similar, the dyslexic students had 109 points and non-dyslexic students had 112 points out of 180 max, for each group. The correlation was not statistically significant (F= 0.777, p 0.127).

Figure 5. Example of region exercise: “What groups of places have similar conditions?”

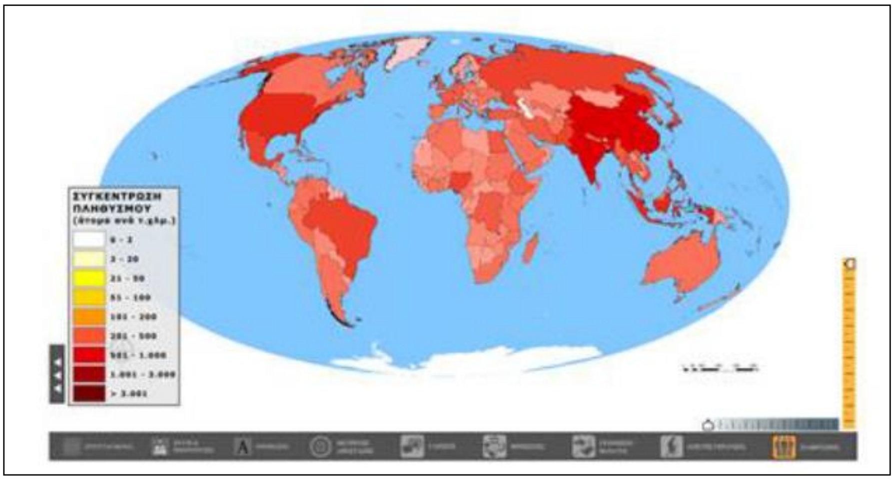
Describing a location. This category of exercises (Fig. 6), was equally difficult for all students in as much as the non-dyslexic students got 105 points and the dyslexic students got 93 points (out of 180 max of each group). This correlation is not statistically significant (F= 3.141, p 0.210).



(Source: Gersmehl & Gersmehl, 2007, p.182)

Figure 6. Example of describing a location exercise: “How do you describe the location of **Σ**?” - Identfication of relative location according to specific features (map coordinates, distance, direction, landform, etc.)

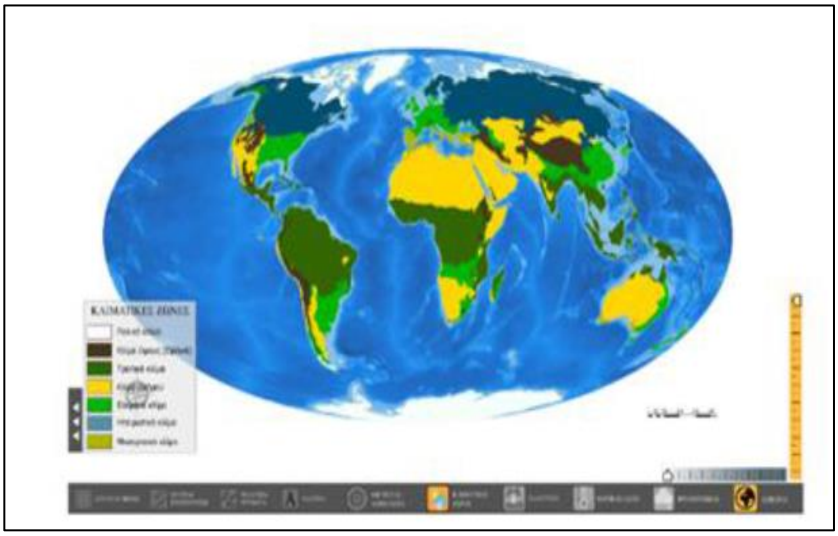
Spatial Comparisons. In this category (Fig. 7), the non- dyslexics gathered 103 points, a score that is far below than the highest score of 180 points. It is remarkable to observe that the score of the dyslexic was only 58 points and that the correspondence between the two teams was quite important (F=47.915, p 0.030).



(World map of population density- Source: http://photodentro.edu.gr/lor/r/8521/2767?locale=el)

Figure 7. Example of spatial comparison exercise: “How are places similar or different?”

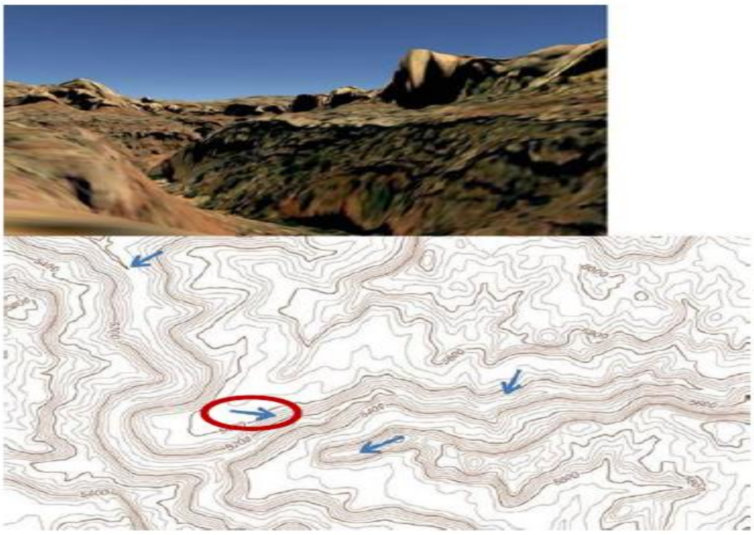
Geospatial analogies. In this exercise (Fig. 8), non-dyslexic students gathered 152 points while dyslexic students gathered 67 points. In this case also the correspondence was statistically significant (F=42.771, p 0.020) and there was a big difference in the performance between the two groups.



(World map of climate zones-Source: http://photodentro.edu.gr/lor/r/8521/2898?locale=el)

Figure 8. Example of spatial analogies exercise: “Does places with similar positions in other parts of the world also have similar conditions or connections?”

2D⟺3D. In this case (Fig. 9) the correspondence was not statistically significant (F= 2.326, p=0.62). The dyslexic students got 155 points while non-dyslexic students got 140 points. Although it is not statistically significant it is essential because it shows us that dyslexic students can respond to a certain type of exercises as well or better than non-dyslexics.



(Source: Jacovina, et al., 2014, p. 15)

Figure 9: Example of 2D ⟺ 3D exercise: Imagine you see the view of the picture above. Circle the arrow, on the map that indicates where and which direction you think you are facing

Total Score in Geographical Thinking

The score obtained by non-dyslexic students in all exercises was 612 while the dyslexics were scored 482 and the maximum score in all exercises of the third part of each team could be 900 points (max 180 for each category of exercises) (Table 2). The result of the analysis indicates that there is a significant difference between two groups (F= 105.515, p 0.042). The results of the third part (geospatial thinking) show that dyslexic students have a lower score than non-dyslexics. The most important observation is that dyslexic students in the 2D and 3D exercises category were superior to those with non-dyslexia, although their difference was not statistically significant. This finding is in line with Eide (2015) suggestions, that dyslexic students are good in 3D exercises.

Table 3

The score of dyslexic and non-dyslexic students in geospatial thinking

	Dyslexic students	SD	Non Dyslexic students	SD	Maximum points
Region	109	0.32	112	0.34	180
Describing a location	93	0.28	105	0.31	180
Spatial comparisons	58	0.16	103	0.30	180
Geospatial analogies	67	0.21	152	0.43	180
2D ←→3D	155	0.44	140	0.41	180
Total score in geographical thinking	482	0.82	612	1.13	900

Table 4
The significance of each correlation in geographical thinking test

Categories of exercises	DF	F	P
Region	3	0.777	0.127
Describing a location	3	3.141	0.210
Spatial comparisons	1	47.915	0.030
Spatial analogies	1	42.771	0.020
2D←→3D	3	2.326	0.621
Total score in geographical thinking	3	105.515	0.042

Conclusions and Suggestions

During the course of any research, the issue of validity is raised. The aim is to remove or minimize the data that make it invalid and have to do with the research project, data acquisition, data succession analysis and subsequent conclusions (Cohen et al., 2008). Also during the course of this research, the researcher was responsible for all legitimate procedures foreseen, such as relevant licenses, by the Ministry of Education, the Parents' Association of Dyslexia and others. In this particular research the sample is limited (25 students with dyslexia and 25 students with no dyslexic behavior) and this doesn't allow the generalization of the results. The answers given by the students do agree with the findings of other researchers.

The survey shows that in most exercises concerning spatial thinking, non-dyslexic students are the ones who outweigh. The main difference between these two groups is noticed in the category of mental rotations and smaller in the categories of plan views. In the third part of the questionnaire concerning geographical thinking in the categories of: region, describing a location, spatial comparisons and geospatial analogies, non-dyslexic students outweigh. Considerable bigger difference and lower performance of the dyslexic students can be noted in the geospatial analogies and spatial comparisons. A notable finding is that dyslexic students performed better, though in slight difference, in 2D ⟷ 3D exercises.

It should be referred that non-dyslexic students did not manage to gather a high score in both exercises categories (in spatial thinking exercises they gathered 677 points out of 900 and in the geographical thinking exercises 612 points out of 900 were accumulated, with 900 as the highest score).

Since Geography is a subject mainly targeting the development of spatial thinking and spatial abilities, our primary aim should be the implementation of current teaching approaches for improving students' performance. This means that there are deficiencies in the students' geospatial thinking and it seems that the subject of Geography is degraded because it is considered a "secondary" course of "minor" importance (Klonari, 2002). With better Geography instruction, students could become adults with increased self-esteem and self-confidence (Klonari, 2012), for this reason, it is imperative to review this concept because, according to the Geographical Education Committee of the

International Geographic Union (CGE-IGU, 1992; 2016) the role of geographic education at the global level is considered very important.

We should also comment on the low performance and scores of dyslexic students (330 points in the categories of spatial thinking exercises and 482 points in the categories of geographical thinking). This is in line with Wadlington's et al. (2008) results that dyslexic students often have high or above-average intelligence in the academic fields but often do not attain their full potential. According to Orphanou (2013) dyslexia, in this area, creates topographical disorders, e.g. in spatial orientation, map reading, etc. Therefore, because dyslexia hinders the effectiveness of learning, it raises the issue of coping, and it is necessary to adopt effective teaching interventions. Dyslexics have a different way of thinking due to the difference between visual capacity and acoustic-vocal memory and on the other hand between visual-spatial competence and verbal strategies (Sotiriadou, 2008). The specific way of thinking of dyslexic students makes necessary the differentiation of teaching procedure, so as to achieve the essential activation and involvement of all students in the teaching procedure. The teacher within this purview of differentiation as a scientist and an expert as well in his field, needs to find and follow teaching procedures through which the aims set by the curriculum will be achieved by all of the students (Tomlison & Eidson, 2003). Contemporary researches focusing on the improvement of certain student's dexterities substantiate the effectiveness of differentiation (Aliakbari & Haghighi, 2014; Chamberlin & Powers, 2010; Joseph et al., 2013; Haghighi, 2012; Landrum & McDuffie, 2010; Reis et al., 2011; Valiandes, 2015).

Bacon (2013), stated that teachers and lecturers have to develop a repertoire of teaching and learning strategies that enable individuals to draw on intact cognitive resources and abilities and to generate and employ cognitive strategies most appropriate to the tasks at hand. The finding strategies can facilitate the students' learning process, even for those with learning disabilities and this also applies to the teaching of geography (Allegri, 2015). The goal of each teacher should be to use appropriate activities and material to help address any difficulties and construct this knowledge system. This will help ensure school progress, school and social integration and successful integration in the active life of the adult. Therefore, the teachers have to support these students, so they can reach their best possible performance. The teacher should adapt his/her teaching based on the skills and deficits of dyslexic students. If educators focus on dyslexic students' strengths, it may be possible to improve the effectiveness of their learning (Wang & Yang, 2011). With appropriate help, teaching methods and educational material, the students could overcome the difficulties they face and improve their geographical and spatial skills. This can be achieved by effectively educating teachers to gain sensitivity and knowledge about dyslexia as well as training them appropriately so that they can use innovative teaching methods and innovative educational material. The active learning based on a visual approach make the lesson more interesting and the learning more effective. Eide (2015) stated that dyslexic people really do show strong 3D spatial abilities. So, the use of 3D maps could make teaching more interesting and effective. It would also be instructive to investigate in which fields dyslexic are gifted. In this way, we might also discover ways to facilitate and appropriate this different learning ability in people with dyslexia (Passadelli & Klonari, 2018).

References

Aleci, C., Piana, G., Piccoli, M., & Bertolini, M. (2012). Developmental dyslexia and spatial relationship perception. *Cortex*, *48*, 466-467.

Aliakbari, M. & Haghighi, J. K. (2014). On the effectiveness of differentiated instruction in the enhancement of Iranian learners reading comprehension in separate gender education. *Procedia-Social and Behavioral Sciences, 98,* 182-189.

Alım, M. (2009). Problems of geography education in Turkey. *Journal of Human Sciences*, *6*(1), 640-651.

Allegri, R. (2015). Geography and disability: a reflection on opportunities offered by teaching geography to dyslexic students. *Journal of Research and Didactics in Geography (J-READING), 2*(4), 85-93.

Appleton, K. (1995). Student teachers' confidence to teach science: Is more science knowledge necessary to improve self-confidence? *International Journal of Science Education, 17,* 357–369.

Bacon, A. M., Handley, S. J., & McDonald, E. L. (2007). Reasoning and dyslexia: A spatial strategy may impede reasoning with visually rich information. *British Journal of Psychology*, *98*(1), 79-92.

Bacon, F. (2013). *The advancement of learning: book I*. Cambridge, UK: Cambridge University Press.

Bekiaris, A., & Simitzi, I. (2012, October). *Dyslexia and ADHD: Characteristics and difficulties.* Proceedings of the Hellenic Institute of Applied Education and Training, 6th Panhellenic Conference, Athens.

Ben-Chaim, D., Lappan, G., & Houang, R. T. (1989). Adolescents' ability to communicate spatial information: Analyzing and effecting students' performance. *Educational Studies in Mathematics*, *20*(2), 121-146.

Bettis, N. C. (2001). Assessment issues in geographic education for the twenty-first century. *Journal of Geography*, *100*(4), 171-174.

Bishop, A. J. (1980). Spatial abilities and mathematics: Education review. *Educational Studies in Mathematics*, *11*, 257-269.

Blazar, D., & Kraft, M. A. (2017). Teacher and teaching effects on students' attitudes and behaviors. *Educational evaluation and policy analysis*, *39*(1), 146-170.

Brooks, C. (2006). Geography teachers and making the school geography curriculum. *Geography*, 91, 75-83.

Brunswick, N., Martin, N. G., & Marzano, L. (2010). Visuospatial superiority in developmental dyslexia: Myth or reality? *Learning and Individual Differences*, 20, 421-426.

Burke, D. J. (2009). Interpreting spatial information and regulating mitosis in response to spindle orientation. *Genes & development*, *23*(14), 1613-1618.

Burnett, S. A., & Lane, D. M. (1980). Effects of academic instruction on spatial visualization. *Intelligence*, *4*(3), 233-242.

Casasola, M. (2008). The development of infants' spatial categories. *Current Directions in Psychological Science*, *17*(1), 21-25.

CGE-IGU. (1992). *International charter on geographical education*. Haubrich, H. (Ed). (1994), Freiburg: International Geographical Union, Commission on Geographical Education.

CGE-IGU. (2016). *International charter on geographical education*. Beijing, August 24th, 2016: International Geographical Union, Commission on Geographical Education.

Chamberlin, M., & Powers, R. (2010). The promise of differentiated instruction for enhancing the mathematical understandings of college students. *Teaching Mathematics and Its Applications: An International Journal of the IMA*, *29*(3), 113-139.

Cohen, B. J. (2018). *The geography of money*. Cornell University

Cohen, L.F., Manion, L., & Morrison, K., (2008). *Methodology of educational research*, Athens: Metaichio (in Greek).

Cohen, S. B. (1988). Reflections on the elimination of geography at Harvard, 1947–51.

Duckworth, A. L., Quinn, P. D., & Tsukayama, E. (2012). What no child left behind leaves behind: the roles of iq and self-control in predicting standardized achievement test scores and report card grades. *Journal of educational psychology*, *104*(2), 439.

Duranovic, M., Dedeic, M., & Gavric, M. (2015). Dyslexia and visual-spatial talents. *Curr Psychol*, 34, 207- 222. DOI: 10.1007/s12144-014-9252-3

Eide, F. (2015). New evidence for dyslexic strengths in 3d spatial reasoning. Retrieved from: http://www.dyslexicadvantage.org/new-evidence-for-dyslexic-strengths-in-3d-spatial-reasoning/

Faggella-Luby, M. N., & Deshler, D. D. (2008). Reading comprehension in adolescents with LD: What we know; what we need to learn. *Learning Disabilities Research & Practice*, *23*(2), 70-78.

Gersmehl, P. J., & Gersmehl, C. A. (2006). Wanted: A concise list of neurologically defensible and assessable spatial thinking skills. *Research in Geographic Education*, *8*(1), 5-38.

Gersmehl, P. J., & Gersmehl, C. A. (2007). Spatial thinking by young children: Neurologic evidence for early development and "educability". *Journal of Geography, 106*(5), 181-191.

Gersmehl, P. J., & Gersmehl, C. A. (2011). Spatial thinking: where pedagogy meets neuroscience. *Problems of Education in the 21st Century*, *27,* 48-66.

Giovagnolli, G., Vicari, S., Tomassetti, S., & Menghini, D. (2016). The role of visual-spatial abillities in dyslexia: age differences in children's reading? *Frontiers in Psychology*, *7*, 1-9.

Gokce, N. (2009). The problems of geography education and some suggestions. *Educational Sciences: Theory and Practice*, *9*(2), 757-768.

Golledge, R. G. (2002). The nature of geographic knowledge. *Annals of the Association of American geographers*, *92*(1), 1-14.

Goodchild, M. F. (2006). The fourth R? Rethinking GIS education. *ArcNews*, *28*(3), 1.

Haghighi, K. J. (2012). *The impact of differentiated instruction strategies and traditional basal instruction on the reading achievement of Iranian EFL students.* (Unpublished master's thesis). University of Ilam, Iran.

Hespanha, S. R., Goodchild, F., & Janelle, D. G. (2009). Spatial thinking and technologies in the undergraduate social science classroom. *Journal of Geography in Higher Education, 33*, 17-27.

Jacovina, M., Ormand, C., Shipley, T.F., & Weisberg, S. (2014). *Topographic Map Assessment. [Measurement Instrument]*. Retrieved from: Newcombe, et al., 2015. THE LAY OF THE LAND: SENSING AND REPRESENTING TOPOGRAPHY. *Perspectives on Spatial Cognition, 10,* 1-57. DOI: http://dx.doi.org/10.4148/1944-3676.1099. (APENDIX A and B).

Jan Bent, G., Bakx, A., & den Brok, P. (2014). Pupils' perceptions of geography in Dutch primary schools: Goals, outcomes, classrooms environment, and teacher knowledge and performance. *Journal of Geography*, *113*(1), 20-34.

Janelle, D. G., & Goodchild, M. F. (2009). Location across disciplines: Reflections on the CSISS experience. In *Geospatial technology and the role of location in science* (pp. 15-29). Springer, Dordrecht.

Jo, I., & Bednarz, S. W. (2009). Evaluating geography textbook questions from a spatial perspective: Using concepts of space, tools of representation, and cognitive processes to evaluate spatiality. *Journal of Geography*, *108*(1), 4-13.

Johnston, J., & Ahtee, M. (2006). Comparing primary student teachers' attitudes, subject knowledge and pedagogical content knowledge needs in a physics activity. *Teaching and Teacher Education*, *22*(4), 503-512.

Jorn, A. F. (1983). Specific reading retardation and working memory: A review. *British Journal of Psychology, 74,* 311-342. DOI: 10.1111/j.2044-8295.1983.tb01865.x

Joseph, S., Thomas, M., Simonette, G., & Ramsook, L. (2013). The Impact of Differentiated Instruction in a Teacher Education Setting: Successes and Challenges. *International Journal of Higher Education*, *2*(3), 28-40.

Khasawneh, M. A. (2012). Spatial ability for children with learning disabilities in hail and its relationship with some variables. *European Scientific Journal,* 8(22), 280-298.

Kirchberg, G. (2000). Changes in youth: No changes in teaching geography? Aspects of a neglected problem in the didactics of geography. *International Research in Geographical and Environmental Education*, *9*(1), 5-18.

Klonari, A. & Kotsanis, J. (2015). Geography in the Photodentro: Theoretical Approach, Methodology, Didactic Approaches, Examples. *Training Laboratory - Training School for School Advisors.* Athens, 25-26 and 29 September 2015 - ITYE "DIOFANTOS".

Klonari, A. & Mandrikas, A. (2014). Experiential in-service teachers' training for the pilot of the new Geography curriculum in Greece: A different experience with tangible results [online]. Review of International Geographical Education Online (RIGEO), *4*(2), 138-154.

Klonari, A. & Passadelli, A. S. (2016). Implementation of ICT in Secondary School Students' Teaching and Learning about Geohazards. *Teaching Science: Research and Action,* 54-55, 8-24. (in Greek)

Klonari, A. (2002, October). "The Status of Geography in Educational System in the Compulsory Schools", Proceedings of the 6th Pan-hellenic Geographical Conference, Thessalonica, Greece

Klonari, A. (2004, October). "The views of the teachers of science and science education for the lesson of Geography", *Proceedings of the 7th Pan-Hellenic Geographical Conference, II,* Mytilene, Hellenic Geographical Society.

Klonari, A. (2007). "Efective teachers: 10th grade students' points of view". In *Proceedings of 5th Pan-Hellenic Conference "Science Education and New Technologies in Education" 5(B)*, 861-868. (in Greek)

Klonari, A. (2012). *Course presentations: General Teaching.* Department of Geography, University of the Aegean (in greek).

Kotsopoulos, D., Floyd, L., Khan, S., Namukasa, I. K., Somanath, S., Weber, J., & Yiu, C. (2017). A pedagogical framework for computational thinking. *Digital Experiences in Mathematics Education*, *3*(2), 154-171.

Koutselini, M. (2008). *Building and differentiating learning teaching in mixed capacity classes.* Nicosia.

Lam, C. C., & Lai, E. (2003). "What is Geography? In the eyes of junior secondary students in Hong Kong. *International Research in Geographical and Environmental Education*, *12*(3), 199-218.

Landrum, T. J., & McDuffie, K. A. (2010). Learning styles in the age of differentiated instruction. *Exceptionality*, *18*(1), 6-17.

Lee, J., & Bednarz, R. (2009). Effect of GIS learning on spatial thinking. *Journal of Geography in Higher Education*, *33*(2), 183-198.

Lee, J., & Bednarz, R. (2012). Components of spatial thinking: Evidence from a spatial thinking ability test. *Journal of Geography*, *111*(1), 15-26.

Lerner, J. (2011). *Learning Disabilities and related mild disabilities (8th Ed)*. Boston, New York: Wadsworth.

Liberman, I. Y., Mann, V. A., Shankweiler, D., & Werfelman, M. (1982). Children's memory for recurring linguistic and non-linguistic material in relation to reading ability. *Cortex*, *18*, 367-375.

Likouri, A. A., Klonari, A., & Flouris, G. (2017). Relationship of pupils' spatial perception and ability with their performance in geography. *Review of International Geographical Education Online*, *7*(2), 154-170.

Livingstone, M., Rosen, G.D., Drislane, F., & Calaburda, A. (1991). Physiological evidence for a magnocellular deficit in developmental dyslexia. *Proceedings of the New York Academy of Science*, *88*, 7943-7947.

Lovegrove, W. J., Martin, F., & Slaghuis, W. (1982). Reading disability: Spatial frequency specific deficits in visual information store. *Cognitive Neuropsychology, 3*, 225-267. DOI: 10.1080/00049538108255295

Marsh, G., Freidman, M., & Welsh, V. (1981). A cognitive development theory of reading acquisition In G.E. Mackinnon and T.G. Waller (Eds.), *Reading Research: Advances in Theory and Practice*. New York: Academic Press, 87-102.

Meisinger, E.B, Bloom, J.S., & Hynd, G.W. (2010). Reading fluency: implications for the assessment of children with reading disabilities. *Ann Dyslexia, 60*(1), 1-17. DOI 10.1007/s11881-009-0031-z

Melekoglu, M. (2011). Impact of motivation to read on reading gains for struggling readers with and without learning disabilities. *Learning Disability Quarterly*, *34*(4), 248-261. Retrieved from: http://www.jstor.org/stable/23053287

National Research Council (NRC). (2000). *How people learn. Brain, mind, experience, and school.* Washington, DC: National Academy Press.

National Research Council (NRC). (2006). *Learning to think spatially*. Washington, DC: The National Academies Press.

Newton, P., & Bristoll, H. (2009). Psychometric success: Spatial ability practice tests. Retrieved from: http://www.psychometric-success.com/aptitude-tests/spatial-reasoning-tests.htm

Orphanou, H. M. (2013). *Learning difficulties.* Teaching Notes, Technological Educational Institute of Epirus, Department of Speech Therapy.

Orton Dyslexia Society Research Committee. (1994). Operational definition of dyslexia. In C. Scruggs (Ed.), *Perspectives, 20*(5), 4.

Passadelli, A. S., & Klonari, A. (2018). Developing Geographical Literacy in Students with Dyslexia: Challenge and Reflection. *In e-proceedings of Hellenic Geographical Society*, Lavrion 12-15 April 2018.

Powell, N., Moore, D., Gray, J., Finlay, J., & Reaney, J. (2015). Dyslexia and learning computer programming. *Innovation in Teaching and Learning in Information and Computer Sciences*, *3*(2), 1-12.

Raths, J. & Diez, M. (Eds.). (2007). *Dispositions in teacher education*. IAP.

Reid, G. (2008). *The Routledge Companion to dyslexia*. NY: Routledge Taylor and Francis Group.

Reis, S. M., McCoach, D. B., Little, C. A., Muller, L. M., & Kaniskan, R. B. (2011). The effects of differentiated instruction and enrichment pedagogy on reading achievement in five elementary schools. *American Educational Research Journal*, *48*(2), 462-501.

Rozin, P., & Gleitman, L. (1977). The structure of the acquisition of reading: II. The reading process and the acquisition of the alphabetic principle. In A. S. Reber and D. 1. Scarborough (Eds.). *Toward a psychology of reading*. Hillsdale, NJ: Erlbaum, 55-141.

Sissanidou, M. (1989). Special Learning Difficulties or Dyslexia. *New Education*, *51*, 57-61, (in Greek).

Sorby, S. A. (2005). Impact of changes in course methodologies on improving spatial skills. *J. Geom. Graphics*, *9*, 99-105.

Sotiriadou, M. (2008). *The effectiveness of teaching methods in students with learning difficulties - dyslexia in primary schools. A case study at a primary school in Cyprus.* (Unpublished dissertation). University of Macedonia, Department of Applied computer science, Thessaloniki, Greece (in Greek).

Stainback, S., & Stainback, W. (1985). *Integration of students with severe handicaps into regular schools*. Reston, VA: The Council for Exceptional Children.

Tafti, M. A., Boyle, J. R., & Crawford, C. M. (2014). Meta- analysis of visual- spatial deficits in dyslexia. *International Journal of Brain and Cognitive Sciences,* 3(1), 25-34. DOI: 10.5923/j.ijbcs.20140301.03

Terlecki, M. S., Newcombe, N. S., & Little, M. (2008). Durable and generalized effects of spatial experience on mental rotation: Gender differences in growth patterns. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition*, *22*(7), 996-1013.

Tomlinson, C. (2003). *Fulfilling the promise of the differentiated classroom: Strategies and tools for responsive teaching.* Alexandria, VA: Association for Supervision and Curriculum Development.

Tomlinson, C. A., & Eidson, C. C. (2003). Differentiation in Practice (Grades 5–9). *Cell*, *505*, 450-5472.

Tsaousis, I. (2008). Measuring Spatial Ability: Development and Psychometric Evaluation of the Ability Spatial Test (AST). Psychology, 15, 411-431. (in greek)

Tzelepi-Giannatou, E. (2008). *School Class Management Issues. "Fast Track Training in School Classroom Management".* YPEPTH – Pedagogical Institute.

Valiandes, S. (2015). Evaluating the impact of differentiated instruction on literacy and reading in mixed ability classrooms: Quality and equity dimensions of education effectiveness. *Studies in Educational Evaluation*, *45*, 17-26.

Wadlington, E., Elliot, C., & Kirylo, J. (2008). The dyslexia simulation: Impact and implications. *Literacy Research and Instruction*, *47*(4), 264-272.

Wang, L. C., & Yang, H. M. (2011). The comparison of visuo- spatial abilities of dyslexic and normal students in Taiwan and Hong Kong. *Research in Developmental abilities,* 32, 1052-1057. Doi:10.1016/j.ridd.2011.01.028

Wong, P. T. P. (1998). Implicit theories of meaningful life and the development of the Personal Meaning Profi le (PMP). In P. T. P. Wong & P. S. Fry (Eds.), *The human quest for meaning: A handbook of psychological research and clinical applications*. Mahwah, NJ: Erlbaum, 111-140.

Zoccolotti, P, de Jong P.F., & Spinelli, D. (Eds.) (2016). *Understanding Developmental Dyslexia: Linking Perceptual and Cognitive Deficits to Reading Processes.* Lausanne: Frontiers Media. DOI 10.3389/978-2-88919-864-1

Biographical Statements

Aikaterini KLONARI is Professor in Geography Department at University of the Aegean. Her research intrest is on Geographic Education and use of ICT in teaching Geography. She teaches a wide variety of courses in undergraduate and postgraduate students. She continuous to conduct research locally and internationally on teaching and learning methodology, Geography Curricula and on GIS in Education.

Anthoula STYLIANI PASSADELLI has BSc in Geology and MSc in Geography and Applied Geoinformatics. These days she is working on her PhD. Her current research intersts are in Geography Education, dyslexic students and spatial thinking, use of new technologies in teaching and learning Geography.