Effectiveness of game-based educational material for developing spatial thinking of dyslexic students: A case study in Lower Secondary School

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Abstract

The aim of this study was to design, apply and evaluate innovative educational material in Geography course in order to improve spatial thinking of dyslexic students, aged 13-14. The design was based on the results of a previous research about differences between dyslexic and non-dyslexic students in the performance of spatial and geographical thinking, where it was identified that children with dyslexia face spatial deficits. Consequently, it is essential to apply appropriate teaching methods, to use specially designed educational material and to take into account students' differences. In this study, an unconventional package of educational material was applied in fifty-four participants (dyslexic and non-dyslexic students) of grades 7 (18 students) and 8 (36 students), during the period of October-November 2020, in Mytilene (Lesvos Island, Greece). The research design required the implementation of the educational activities in whole-class contexts and the objective was to determine whether the intervention was more effective for students of varying spatial skill. The package includes a comic book, a domino game, 2D maps and their corresponding 3D models. Five teaching hours were needed for the application of the instructional material. The results indicated that the designed tools stimulate students' interest and facilitate the teaching and learning of specific spatial skills. Additionally, the results showed that in this game-based environment, beside students' (dyslexic and non-dyslexic) higher achievement (87% of them had better scores at the post intervention test), the commitment in group activities was increased and there was higher motivation for Geography.

Keywords: Geography, spatial abilities, game-based learning, dyslexic students

1. Introduction

The understanding of space is a fundamental need. One concept that related to space is spatial thinking. 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), to structure problems, to find answers, to express and communicate solutions (Klonari & Passadelli, 2019a). According to Gersmehl & Gersmehl (2011) the process of spatial thinking is very complex. These researchers based on neurology studies, developmental psychology and other sciences argued

that spatial thinking is structured by 7 concepts: spatial hierarchy, spatial comparisons, spatial transitions, spatial analogies, spatial auras, positioning and floor plans. Since spatial science is directly connected with Geography, the Geography teachers should teach spatial science with an interactive way in order students to develop it. Klonari & Passadelli, (2019b) stated that although all students face difficulties in spatial thinking, the issue for dyslexic students is more acute. Dyslexia is a learning disability that affects various areas of academic performance (Passadelli et al. 2020). It was proven that dyslexic students' intelligence is normal (Rajapakse et al., 2018), but they think differently. However, if teachers apply appropriate teaching methods and educational material, dyslexic students could overcome their difficulties (Passadelli et al., 2020).

Current developments in education have led to a number of changes in the understanding of learning objects. Satisfaction of modern educational needs requires the preparation of teaching materials with new perspectives in the classroom. The application of appropriate teaching material has several positive results, such as the increase of efficiency, the active participation of students (Tekmen-Araci, 2019) and the provision of lifelong learning (Akcanca, 2020). The use of appropriate activities and educational material should be the goal of every teacher in order to achieve students' best performance. Exclusive use of the book, without the support of additional material, risks reducing students' interest and therefore the effectiveness of learning. Regarding to geographical education, it has been observed that in recent decades there is an increased interest to improve its quality in terms of content, teaching methods and curricula (Bettis, 2001; Klonari, 2004; Brooks, 2006; Klonari & Mandrikas, 2014; Aliman, 2019).

The main purpose of this research is to study the impact of a set of game-based tools, designed by the researchers, on the achievement of specific learning objectives related to the development of students' spatial thinking. Moreover, the educational material has been designed to give clear benefits for dyslexic students, in order to overcome their difficulties.

2. Methods

2.1 Participants

The survey was carried out in a public Junior High School on Lesvos Island, Greece, in 2020. A sample of 54 students participated, 28 girls and 26 boys. From these students 18 (10 girls, 8 boys) were from 7th grade and 36 (18 girls, 18 boys) from 8th grade. In addition, 9 students (2 of 7th grade and 7 of 8th grade) 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.

2.2 Educational material

The educational material was created according the Gersmehl & Gersmehl's (2011) categories of spatial thinking. More specifically, for the development of spatial hierarchies' skills, a board game (dominoes) was created (Figure 1). This game is played by two students who should create a spatial hierarchy using a set of coloured and laminated cards. The total number of cards is 18, but not all cards could be used. The cards depict some continents, countries, cities and sights. Two spatial hierarchies could be made from all cards.

Figure 1: The two spatial hierarchies made by domino cards

For the development of understanding and interpreting maps and other geographic representations, 2D maps (digital elevation models) and their corresponding 3D models (computer-based relief models) were created. Seven 3D miniature representations of the earth's surface were printed with the use of computer-based techniques (converting digital elevation)

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by Terrain2stl (Figure 2)¹. In detail, two 3D models which represent an area of Mount Everest, two 3D models represent an area of the Caucasus Mountain Range and three 3D models represent a lowland area of Switzerland. The goal of the activity was to enable students to compare and identify 2D maps with satellite maps and 3D models.

Figure 2: 3D terrain models

Finally, for the development of spatial comparisons, positioning and auras, one combined activity was performed, based on a comic book (Figure 3) that was created using Storyboard <https://www.storyboardthat.com/storyboard-creator> software (it is online and free). The comic book is in Modern Greek language, consists of 24 coloured pages and it describes a short story about melting ice. Students should fill in the blanks for some of the dialogues.

Figure 3: All pages of the comic book

¹ <http://jthatch.com/Terrain2STL>

2.3 Research tools

The study employed 3 pre-test and 3 post-test questionnaires, i.e. one pre-test and one post-test questionnaire for each one of the three educational games. Each pair of questionnaires (pre- and post-test) contained the same questions in order to compare the development of students' spatial skills and to assess the effectiveness of the educational material.

- Spatial hierarchies' questionnaires contained 4 close-ended questions. Each question was graded with 5 points.
- The questionnaires for spatial comparisons, locations and spatial auras contained 4 questions (one close-type and three open-type). Each question was graded with 5 points.
- The questionnaires for understanding and interpreting maps (2D and 3D) contained 2 close-ended questions. Each question was graded with 10 points.

2.4 Procedure

Initially, the researchers contacted the High School principal by phone to ask for permission. Afterwards, they met with the geography teachers of 7th and 8th grades to clarify the purpose of the research and the steps to be followed. All educational activities were implemented by the researchers, while school teachers were classroom observers. In the following paragraphs we briefly present the implementation of the activities.

Spatial hierarchies: After the pre-test questionnaire, the educational activity was introduced and the students played the domino game. Finally, they completed the post-test questionnaire. This board game was applied in 19 8th grade students and lasted one teaching hour.

2D and 3D models: Initially, students answered the pre-test questionnaire and then they were given worksheets with some activities, a 2D map of terrestrial relief, a satellite map and a 3D model. All "maps" represented the same area. Furthermore, each group of students was given a watercolour paint pack and brushes. The students accomplished the activities and at the end

they painted the white 3D models with appropriate colours, depending on the relief and elevation of the area. Afterwards, students answered the post-test questionnaire. This activity was implemented in 17 8th grade students and lasted two teaching hours.

Spatial grouping, correlations, auras and positioning: The students in the previous Geography courses had been taught about the climate and related concepts. This teaching intervention was implemented in 18 7th grade students and lasted two teaching hours. At the beginning, students answered the pre-test questionnaire and then they had to complete the comic book. Finally, they answered the post-test questionnaire.

3. Results

The educational material's evaluation was based on students' answers at post-test questionnaires, on their participation and engagement to the activities, as well as on the results of games (products) they "played" during the intervention. This last part was analysed in: (a) how well they responded to the creation of the spatial hierarchies through dominoes, (b) the correct completion of the comic dialogues and (c) the correct application of colours in the 3D models, as well as the comparison of 2D with 3D models.

At the board game (domino) the results of pre-test questionnaire showed that all students (dyslexic and non-dyslexic) had significant problems at spatial hierarchies. Nevertheless, all students after the teaching intervention and the application of domino game, improved their performance. All student teams placed the cards with spatial hierarchies correctly. The maximum score that non-dyslexic students could totally have at each question was 80 points and for dyslexic students was 15 points (since dyslexic students were only three). From the sums of student's answers (Figure 4), we observe that all students had better performance after board game and they improved their initial knowledge. While initially both student teams had very low sums, after the teaching intervention the sums had big difference. The students' sums in post-test questionnaire were well above the base (40 and 7.5, respectively).

Figure 4: The sums of students' answers in pre- and post-test questionnaires about spatial hierarchies

In more detail, the answers' means of the non-dyslexic students increased significantly. In question 1 of pre-test questionnaire the mean was 1.13 (Std. deviation = 0.957), while in post-test one was 4.12 (Std. Deviation = 1.094). In question 2 the results were similar with question 1. The mean in pre-test questionnaire was 1.44 (Std. Deviation= 2.500) and the mean in the post-test one was 4.00 (Std. Deviation = 1.014). In question 3 the non-dyslexic students had better performance in pre-test questionnaire than in other questions, so their students' test scores did not rise very much afterwards. In pre-test questionnaire, the mean was 3.12 (Std. Deviation = 1.088) and in the post-test one the mean was 3.75 (Std. Deviation = 0.966). In question 4 in the pre-test questionnaire students received the lowest mean of the scores, 0.69 (Std. Deviation= 2.236) while in the post-test one the result was similar with other questions. The mean was 3.81 (Std. Deviation= 1.167). The dyslexic students in all questions of pre-test questionnaire received the lowest scores, mean 0, except in question 4 where they had mean 1. In post-test questionnaire, in question 1 the mean was 3.33 (Std. Deviation = 0.577), in question 2 was 2.67 (Std. Deviation = 0.577), in question 3 was 3.33 (Std. Deviation = 2.887) and in question 4 was 3.67 (Std. Deviation = 1.155).

At 2D terrestrial relief and satellite maps, as well as at 3D terrain models, the results of pre-test questionnaire showed that all students (dyslexic and non-dyslexic) had significant problems. Nevertheless, all students after the teaching intervention and the application of the activities with the 3D printed models, improved their performance. The maximum score that non-dyslexic students (they were 13) could totally have at each question was 130 points and for dyslexic students was 40 points (since dyslexic students were four). At figure 5 can be observed that while in pre-test questionnaire the sums were less than the base, in the post-test one the sums were well above of it. Additionally, dyslexic students in question 2 of post-test questionnaire received the maximum score. Moreover, both teams improved their performance (increasing their means). For non-dyslexic students, the mean score in the first question of the pre-test questionnaire was 4.77 (Std. Deviation = 2.774), while in the post-test one was 8.77 (Std. Deviation = 1.536). The mean score in the second question of the pre-test questionnaire was 1.54 (Std. Deviation = 1.854) and in the post-test one was 8.46 (Std. Deviation = 1.450). For dyslexic students, the mean score in the first question of the pre-test questionnaire was 3.50 (Std. Deviation = 1.915) and in the post-test one was 9.50 (Std. Deviation = 1.000). In question 2 of the pre-test questionnaire the mean was only 0.50 (Std. Deviation = 1.000), while in the post-test one was 10.00 (Std. Deviation = 0.00).

Figure 5: The sums of students' answers in pre- and post-test questionnaire about 2D and 3D models

Additionally, almost all students used the correct colours to paint the earth's relief in 3D models (Figure 6).

Figure 6: 3D terrain models painted by the students

Furthermore, the results for the activity on the comic book were similar to the other two activities. All students in the pre-test questionnaire did not perform well, while in the post-test one their performance improved significantly. In Figure 7 the sums of dyslexic and non-dyslexic students in pre- and post-test questionnaires are showed. The maximum score for non-dyslexic students was 75 and for dyslexic was 45 points. For non-dyslexic students in the pre-test questionnaire the sums were low, but after the teaching intervention they increased; in question 2 the non- dyslexic students received the maximum score. In more detail, in question 1 of the pre-test questionnaire the mean was 1.067 (Std. Deviation = 1.158) and in the post-test one was 4.413 (Std. Deviation = 1.073). In question 2 of the pre-test questionnaire the mean was 3.00 (Std. Deviation = 2.535), while in the post-test one was 5.00 (Std. Deviation = 0.00). In question 3 of the pre-test questionnaire the mean was 1.00 (Std. Deviation = 1.267) and in the post-test one was 4.167 (Std. Deviation = 1.219). In question 4 of the pre-test questionnaire the mean was 2.00 (Std. Deviation = 2.535), while in the post-test one was 3.00 (Std. Deviation

= 2.535). Hence, students improved their performance in all questions. In addition, concerning dyslexic students, the mean value in first, third and fourth questions of the pre-test questionnaire was 0.00 (Std. Deviation = 0.00), while in the post-test one the mean value in question 1 was 2.667 (Std. Deviation = 0.923), in question 3 was 3.33 (Std. Deviation = 1.443) and in question 4 was 5.00 (Std. Deviation = 0.00). In the second question of the pre-test questionnaire the mean value was 1.67 (Std. Deviation = 2.887) and in the post-test one was 5.00 (Std. Deviation = 0.00). Moreover, the students completed the comic book correctly and they were led to the right conclusions.

Figure 7: The sums of students' answers in pre- and post-test questionnaires about spatial correlations, spatial auras, positioning and spatial grouping

4. Conclusion

In this study, we examined whether the package of educational material designed by the researchers, based on dyslexic students' difficulties, is effective. The aim of this package was to help students to overcome their difficulties in spatial thinking. The "games" of the package applied in mixed ability classes (with dyslexic and non-dyslexic students) of 7th and 8th grade of a Junior High School during the Geography course, because, according to "Geography for Life; National Geography Standards" (Bednarz, et al., 1994) and more recently to "Geography Education National Implementation Program (GENIP)" that revised National Geography Standards (Heffron, 2012), as well as to the Greek National Geography Curriculum (Official Gazette, 2003) and to the revised Greek National Geography Curriculum, 2011 (Klonari, 2015), enhancing spatial thinking is one of the key goals of geography education. Appropriate methods that can be implemented in teaching, can facilitate learning processes even in students with learning disabilities (Passadelli & Klonari, 2020). These teaching and learning methods could also be applied to Geography, promoting students' spatial thinking (Feeney, 2003; Allegri, 2015; Passadelli et al., 2020). Game-based teaching methods are often used in teaching Geography (Ye et al., 2020; Sim et al., 2021) and games are very helpful for dyslexic students (Vasalou et al., 2017). Evaluation results showed that all students with low achievement at spatial hierarchies' skills in the pre-test questionnaire, had better performance in the post-test one because of the implementation of the board game (dominoes) in teaching and learning.

In addition, comics can be used as an important and powerful complementary teaching tool in various educational environments (Berkowitz & Packer, 2001; Cimermanová, 2015; Rajendra, 2018) and should be considered as an innovative teaching method with great potential for all levels of education (Rocamora-Pérez et al., 2017; Deligianni-Georgaka & Pouroutidi, 2016). Astuti et al. (2014) highlight the importance of visual thinking in teaching and learning, because the combination of images and texts makes the learning process more attractive and helps students to change their perspective on it. The comic is easy to read and have a visual appeal to the students (Sukri et al., 2020), and help students to develop some skills easier than a traditional textbook (Akcanca, 2020). In addition, comic could facilitate learning for those with learning disabilities and promote social awareness (Sime & Themelis, 2020). The comic is an effective tool that create positive attitudes to students and help them to develop their critical thinking.

Furthermore, maps are the main tool used for geographical education (Klonari & Koutsopoulos, 2005) and provides geospatial information. Maps are symbolic representation of geographical features and visualize selected characteristics (social, physical, etc). Paper maps, digital maps, interactive maps, virtual spheres or 3D maps are important tools for teachers, because they can offer significant benefits in increasing students' geographical knowledge and understanding. It was proven that dyslexic students have advantages at 3D representations (Eide & Eide, 2011; Klonari & Passadelli, 2019a). This is also confirmed by this research. 3D terrain models allow students to understand earth's relief easier than the 2D maps, as they don't need to imagine how an area is really like only from the colours or the contour lines.

In conclusion, applying appropriate teaching methods and educational material, students could overcome the difficulties they face and improve their geographical and spatial skills. Focusing on students with dyslexia, it would be very helpful to explore in which areas they have particular abilities. In this way, we could choose teaching approaches that would develop this different learning ability of dyslexic students (Passadelli & Klonari, 2018). Therefore, teachers need to be supportive and adapt their teaching based on the skills and deficits of their students (Klonari & Passadelli, 2019b). Consequently, it is necessary to apply alternative teaching strategies that could be based on new technologies to provide effective teaching and learning for all students (Abdurrahman et al., 2019). The presented work is another proof of it.

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