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PAPER

Mobiles & ICT Based Interventions for Learning Difficulties in Geometry

Viktoriya Galitskaya, Athanasios S. Drigas(✉)

Net Media Lab Mind – Brain R&D IIT – N.C.S.R. "Demokritos", Athens, Greece

dr@iit.demokritos.gr

ABSTRACT

The difficulty faced by students in Geometry (ageometria) is a relatively new learning challenge that has yet to be extensively explored. Early detection and intervention are crucial. Students with dyslexia, like other students with special learning difficulties, face challenges in working memory. In addition, solving a geometric problem requires comprehension of pronunciation and numerical processing. In addition, solving a geometric problem requires comprehension of pronunciation (in which students with dyslexia lag) and numerical processing (in which students with dyscalculia lag). For this reason, this article presents interventions aimed at enhancing working memory and improving reading and numerical skills with the help of new technologies.

KEYWORDS

STEM, STEAM, robotics, educational robotics, problem solving, ageometria, working memory, applications, augmented reality, mobile and tablet apps, ICT

1 INTRODUCTION

The contribution of Information and Communication Technology (ICT) to both general [1]–[3] and special education [4]–[7] has been confirmed by numerous studies. Students argue that they make teaching learning more enjoyable and fun [8]. ICTs are familiar to students [9] as they have been exposed to their use since pre-school age. For this reason, almost all researchers choose in their research to use programs and applications with the help of which they can first identify a learning disability [10], [11] and then carry out the appropriate intervention [12]. Some of the technologies used in special education that have positive benefits are:

- Internet [13];
- Smartphones apps [1], [14]–[16];
- Whiteboards [2];
- Virtual and augmented reality [3]–[7], [9];

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- Intelligence tutoring techniques [11];
- Science Technology Engineering Mathematics (STEM) [10]; and
- Video games [12].

In recent years it has been proven that smartphones or tablets have made students change their attitude towards mathematics. These devices enable students to improve their mathematical thinking. Apps used for this purpose connect mathematics to everyday activities and ask for the solution of problems with the help of arithmetic or geometry [17].

2 ORIGIN OF GEOMETRY

The roots of Geometry go back many centuries. The word "geometria" comes from the words "Geo" which means earth and "metria" which means measurement in the Greek language. According to historians, the Egyptians were the first to discover Geometry in their attempt to measure the area of their fields, which were flooded every year by the Nile River. In addition, the ancient Egyptians, the Babylonians, the Chinese, and the Indians studied and applied Geometry. All these people may have applied Geometry, but they were empirical, they did not follow any rules and they did not try to give logical proofs, the goal was only to solve the problems. The revolution was brought about by Greek mathematicians, who tried to fill these gaps.

A lot of research proves that natural Geometry is innate [18]–[21] and is an essential element for the reconstruction of new cognitive skills [22]. Geometry exists around us, many objects in the environment take the form of two-dimensional or three-dimensional shapes. People use Geometry in their daily lives even if they do not understand it. For example, when they want to park the car or cross the road.

3 GEOMETRY LEARNING DISABILITIES

Ageometria is a relatively recent subject of study in special education and indicates the difficulty that students have in understanding, processing, and solving geometry problems [23].

Difficulty in learning geometry can be due not only to the complexities involved in learning geometry but also due to some factors that also appear to affect complex geometric learning, including computational skills, working memory (WM), visual cues, and numerical problem-solving ability.

The causes of ageometria are multifactorial and are due to:

- Neurological causes [24]–[26];
- Problems with working memory and its subsystems [27]–[30];
- Attention problems [31]; and
- Mathematical anxiety [32], [33].

4 AGEOMETRIA AND WORKING MEMORY

Children with all types of learning disabilities have working memory deficits [28], [34], [35]. Children with learning disabilities have extensive deficits in the WM and the severity of deficits in the WM varies according to the sector and type of learning disabilities [16], [36]–[38].

According to research, children with ageometria have deficiencies in the WM because to be able to solve a geometric problem they will need:

- Performing arithmetic operations [39]–[41]; and
- The temporary preservation and storage of verbal and audiovisual information [42]–[45].

Deficiencies in visual-spatial working memory explain the difficulties of students with ageometria [46]. Visual working memory is a visual-spatial storage system and is an important predictor of students' performance in solving geometric problems [42], [47]. Students' experience and logical reasoning have been shown to play a critical role in the development of geometric skills, and there is no doubt that inappropriate geometry [48] is an important reason for students' failure to learn geometry.

In 2018, Marzia Bizzaroa et al. conducted a study that aimed to find the reasons that contribute to the failure of students in geometry. Fifth and sixth-grade students participated in the research. The students were divided into two groups, one group consisted of students who had ageometria and the other was the control group. The children were given problems (arithmetic and geometry) that they had to solve. Based on the results, the researchers concluded that children with geometry have a problem with the WM (verbal and visual-spatial memory). A very important finding was that children who fail in geometry (children with ageometria) are different from those who fail only in arithmetic (children with dyscalculia) [49].

In 2021, Maria Chiara Fastame conducted a similar study on students in Italy and confirmed that children with learning difficulties in geometry show deficits in different sections of the WM [50] relative to those with other learning disabilities.

Solving geometric problems requires a series of steps. Students need to:

- interpret a problem;
- process the data given to them;
- understand the information; and
- transfer the information to a mathematical, visual, or mental model to solve the problem (Mayer, 2013).

Research proves that students with learning disabilities in geometry cannot represent and develop strategies that will lead to problem-solving [51].

5 AGEOMETRIA AND ICT

Working memory is responsible for important processes required to solve a geometric problem such as reading, understanding word problem, and performing the necessary arithmetic operations. Research shows, good performance in geometry is directly related to working memory.

5.1 Robotics and STEM

The use of STEM in education has been shown to [52]:

- help students with attention deficit disorder;
- improve high-level skills;

- have positive problem-solving results; and
- help in maintaining knowledge.

Zhong and Liying in 2018 conducted a literature review of 20 studies to test whether training robots can help learn arithmetic and geometry. Their research sample included people aged 3 to 33 years. They noticed that in the majority of the researches LEGO robots were used and they tried to check if the educational robots help to improve the mathematical skills when:

- the student interacts with the robot;
- programs or
- build and programs the robot.

Most research has shown that students improve their skills better when they come in contact with the robot [53]. There are many kits such as LEGO WeDo, LEGO Mindstorms, and Robotis Dream that are used in robotics education and help students of all ages hone their skills in many areas [56].

In Spain, a pilot program was held that included teaching students through STEM. The study involved sixth and seventh graders who conducted 26 (6th grade class) and 28 (7th grade class) sessions, once a week. Seven different Fischertechnike set were used for the study and the children were divided into groups of three. Before the start of the research, the children went through a process of checking their spatial ability so that results can be compared with them after the sessions. During the sessions students had to program the robots and solve engineering problems using arithmetic and geometric knowledge. At the end of the sessions, the trainers observed that the tutors were highly motivated to learn throughout the duration of the program. It was also found that the improvement of the spatial ability of the students resulted in the understanding of algebraic, geometric, and mechanical concepts [54].

In Israel, a study was conducted by Einat Brainin, Adina Shamir, and Sigal Eden, focusing on kindergarten students. The aim of the research was to check if the intervention program they used can improve the visuospatial perception of the students. Students were tested before the intervention, which included the 10 sessions are listed for testing. Sessions included activities targeting spatial relationships, visual-memory, and mental rotation. The intervention program was carried out with the help of the Bee-Bot robot, which is suitable for preschool students. The findings showed that the use of the programmed robots during the intervention had positive effects on spatial relations and mental rotation [55].

Another intervention program was carried out with the help of the Robotis Dream ER kit in Turkey. Primary school students participated in the research and the sessions lasted 31 weeks. The students were tested before and after the intervention so that the results could be compared. Each session included a different activity and with the end of each session the difficulty of the activities increased. The results of the research confirmed that the use of robotics in education improves students' spatial perception [56].

5.2 Applications for mobile and tablets

Video games have been available in the market for more than 40 years, but their integration into the educational process has only occurred in recent decades [57].

Multiple studies conducted on student learning using games have shown that students find it fun and increase motivation to learn [58].

Skiada and her colleagues have developed the EasyLexia mobile app aimed at students aged 7 to 12 with learning disabilities. The aim of the application was to improve students' language and math skills. The application included four sections [59]:

1. Words: The games in this section were aimed at improving students' reading ability, focusing mainly on comprehension.
2. Numbers: It focused on developing and supporting mathematical logic so that students could solve mathematical problems.
3. Memory: It involved activities with geometric shapes that improved visual-spatial and short-term memory.
4. Books: The aim of this section was to enhance the concentration of students.

The application was created with the help of students, who tried the application and made their observations. The results from the use of the application based on the researchers proved to be positive [59].

The APODYT application was designed by a team of researchers and is aimed at students with learning disabilities such as dyslexia, dyscalculia, and ageometria. The application was designed to help students maintain their attention, improve their working memory, and other language and math skills [60].

Auto Train Brain is an application specially designed for children with special learning difficulties. This application can be easily installed on mobiles and tablets, utilizing neurofeedback and multi-sensory learning [61].

The Auto Train Brain app was used in a study conducted by Turkish researchers to test its effectiveness. The research involved 30 students who were divided into two groups, the experimental and the control group. Both groups received long-term intervention and had positive results at the end of the program. The results showed that Auto Train Brain had positive effects on left temporal and left parietal lobe functions. In addition, participants demonstrated improvements in various areas, including improved letter perception, orthographic decoding, working memory capacity and reading comprehension, social communication, forward digit span, and backward digit span [61].

5.3 Virtual reality

In 2022 Lu, Cho, and Zou published an article in which they examined the potential of virtual reality to enhance working memory. The research yielded positive results, indicating that the participants found this method of learning to be effective and innovative [62].

Virtual reality games can be beneficial for children with learning disabilities, including those experiencing ageometria. Students with ageometria may struggle with some aspects of working memory, and improving it can have a significant impact on improving their geometry skills.

Minecraft is a virtual reality video game that has been used in the classroom and in research since its release.

Bos, Wilder, et al. conducted research involving elementary school students, utilizing Minecraft as a tool to teach geometric concepts, shapes, etc. Their study, along with subsequent research, highlighted the usefulness of Minecraft in facilitating learning across various subjects. Importantly the game was found significantly contribute to the development of the participants' spatial abilities [63].

Another example is the Geometry Explorer game, which utilizes virtual reality systems to enhance the spatial abilities of students who have difficulty in learning geometry. The application presents the student with 3D geometric shapes that they can manipulate, aiding their understanding of concepts such as volume. In addition, the game records the time taken by the students for each activity [64].

In 2022, a study was conducted with second-year high school students from Taiwan. The research utilized a virtual reality mathematics immersive geometry learning system. Before the intervention, the students were assessed on specific geometric concepts. Following the intervention, the students exhibited increased self-confidence in their knowledge, and their test performance improved, resulting in better results [65].

NeoTrie is a virtual reality software that offers a 3D dynamic geometry experience. This software is suitable for teaching and learning geometry. It provides activities that aid in understanding stereometry, three-dimensional visualization, topology, and the conversion of figures between two-dimensional to three-dimensional representations and vice versa. A study conducted in Spain demonstrated that dynamic geometry systems (DGS), such as NeoTrie, can enhance students' visuospatial perception. In addition, students who used the NeoTrie software showed improvement in their geometric skills in the specific sections they were taught, along with the development of visual structural reasoning [66].

VirGO is a virtual geometry application specifically developed for smartphones, utilizing augmented reality technology. The creators of VirGO aimed to design the app student-friendly, ensuring that they do not get bored, tired, or frustrated. The app was tested on students from three junior high schools in Padang, and the results indicated that learning geometry through the app helped students gain a better understanding of geometric concepts [67].

6 CONCLUSION

In conclusion, it is crucial to emphasize the significance of the digital technologies in education domain, particularly in addressing learning disabilities. These technologies have proven to be highly productive and successful, facilitating and enhancing assessment, intervention and educational processes via mobiles, which have enabled educational activities to be accessible anywhere [68]–[72]. A wide range of ICT applications has emerged as core tools in supporting education [11], [73]–[98], The integration of AI, STEM, and robotics has elevated educational practices to new levels of performance [99]–[103]. Educational games have transformed the learning experience into a friendly and enjoyable interaction [5], [104]–[106]. Additionally, the enhancement and combination of ICTs with theories and models of metacognition, mindfulness, meditation, and emotional intelligence cultivation [34], [107]–[132] as along with environmental factors and nutrition [133]–[136], have shown to accelerate and improve educational practices and outcomes, especially in the context of intervention for learning disabilities.

In recent years, a significant amount of research has been carried out on learning disabilities to better understanding their causes, better detection and early intervention. Learning disability in geometry is a multifactorial specific learning disability that can also be identified in students with:

- Dyscalculia, as solving geometric problems requires performing arithmetic operations; or
- Dyslexia, as the solution of a geometric exercise requires the understanding of word problem.

The detection of students with learning difficulties in geometry poses a challenge due to the fact that children with typical development have considerable difficulty in understanding and solving geometric exercises. In order to make it easier to separate students with ageometry from students who simply have difficulty in geometry [137], it is crucial to check the sections of working memory such as VisuoSpatial sketchpad, Central executive, Phonological loop, Short-term memory and Semantic loop [34]. Students with special learning difficulties tend to lag behind in many aspects of working memory.

For the above reasons, the intervention should focus both on improving working memory skills, as well as on reading and arithmetic skills.

Information and communication technology help to create such planned interventions. The choice of ICT is not accidental as the students have come to terms with their use and are motivated to learn. This article presents research that implemented interventions utilizing STEM based mobile and tablet applications, as well as virtual reality applications, which have gained popularity in recent years due to student's preferences.

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8 AUTHORS

Viktoriya Galitskaya is a research associate Net Media Lab Mind – Brain R&D IIT – N.C.S.R. "Demokritos", Agia Paraskevi, 153 10, Athens, Greece (e-mail: vgalitskaya@yahoo.gr).

Athanasios S. Drigas is a Research Director Net Media Lab Mind – Brain R&D IIT – N.C.S.R. "Demokritos", Agia Paraskevi, 153 10, Athens, Greece (e-mail: dr@iit.demokritos.gr).