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Improving Geometry Teaching with Scratch

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ABSTRACT

Scratch is a tool for initial learning of programming, but also for creating educational and entertainment content, making mathematical and scientific projects, simulating and visualizing experiments. This paper examines the effectiveness of Scratch's application in mathematics, in the study of basic geometric shapes. The analysis has shown that there is a statistically significant difference in achievement among students who have learned the basics of geometry based on the perception and recognition of geometric shapes on models and bodies and those who have used the programs implemented in Scratch. The results obtained are in a positive correlation with the students' overall school performance and show that there are no differences in achievement between boys and girls. Scratch is an environment that has allowed mathematics to become more interesting and interesting to students.

Keywords: geometric shapes, mathematics, Scratch, students, teachers

INTRODUCTION

Scratch is a visual programming language, developed primarily for children aged 8 to 16, but is used by people of all ages (Naz et al., 2017). This simple and interesting programming language makes it easy to understand basic programming principles. Programming is a very important part of the literacy of contemporary society - and when people learn to program, they actually learn important problem solving strategies, designing and designing projects (Mladenovic et al., 2017). Learning programming is painstaking beginners regardless of their age.

Children learn best through the game and there is no better way to get acquainted with the programming world than to make their own game. Scratch allows to create creative stories, games, and animations (Resnick et al., 2009). By making games and animations, children learn the basics of programming logic, without learning the complicated syntax of standard programming languages. They use visual components that are assembled similarly to blocks (Maloney et al., 2010). Scratch is an extraordinary learning environment, creative thinking and systematic programming conclusions.

Scratch is not just a useful pedagogical tool for introducing students into the programming concepts, but its benefits are much higher. It provides students with the ability to create an application (learning object), which will be used in teaching (Batista & Baptista, 2014). Students become active participants in the creation of teaching materials, where in their work with teachers they develop their creative abilities. The material stops being just a lesson that you need to learn, but it also becomes a theme for animation or video game. The students develop creativity, creativity, team spirit and other qualities needed to work on creating a new knowledge.

Scratch can be used at all educational levels and in all subjects - from mathematics and physics, through computer science, to social sciences or art. Mathematics is the subject closest to the programming is (Calao et

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al., 2015). The use of Scratch as a pedagogical tool for presenting mathematical concepts is more natural than, for example, the use of Scratch in art. Most mathematical principles can be expressed in programming languages, and thus learn in programming (Batista & Baptista, 2014).

Scratch enables easy, effective and interesting learning of mathematics. It can be used in teaching and learning basic mathematical principles within arithmetic and geometry (Joini et al., 2015). For example, a program can be implemented that performs four basic computational operations (addition, subtraction, multiplication, and division), quadriates numbers, distinguishes even and odd numbers, calculates the range, displays various geometric shapes or bodies. What is most important, you can create various games and quizzes to test knowledge in mathematics.

According to Schmidt-Thieme (2009), the description of the geometric construction is an algorithm that can be translated into a computer language. The computer program can be realized iteratively, so that students learn particular parts of the geometric design, test them separately, and ultimately connect them in their entirety. Foerster (2016) describes the use of Scratch to display polygons and tessellations, which require the application of modulation in programming. Scratch proved to be a good tool for the construction of congruent triangles, allowing the realization of all elements of dynamic geometry (Foerster, 2015).

The Scratch features Turtle geometry, first introduced in the language Logo for more than fifty years. The term Trutle geometry refers to the geometry described by relative movements versus absolute coordinates (Koschitz & Rosenbaum, 2012). A relative movement is intuitive, because it can rely on knowledge of the movement of one's own body in the space. Each shape in Scratch has the ability to behave like the Logo Turtle: it can be given position, path and direction of movement, and when moving it can leave a trace (Crook, 2009).

Scratch provides a range of different ways to bring students basic geometric concepts in an interesting and creative way. Students can easily create lines and basic and complex geometric shapes, for example, a house that consists of squares and triangles. With all this in mind, the research of the effectiveness of Scratch's application in geometry is very important. Learning geometry encourages the development of students' perceptions of the environment and the world around them. They become more skilled in describing, presenting and using their own environment (Vlasnovic & Cindric, 2014).

METHODOLOGY

The subject of the research is to examine the effectiveness of Scratch's application in mathematics. The aim of the study was to determine whether there are differences in the learning of basic geometric shapes in the traditional way and using Scratch. Tasks of the research are:

- determine student achievement for testing after an experiment has been conducted
- determine whether there are differences in achievement between boys and girls
- determine the frequency of the accuracy of the tasks at the final test
- determine the connection between general school achievement and achievement in the final test

In this research an experimental method was applied. The experiment included 106 students of the third grade of elementary school, divided into two equal groups. One group taught the basics of geometry on the basis of spotting and recognizing geometric shapes on models and bodies, and the other using a program implemented in Scratch. Groups were formed randomly, or according to students' wishes. Both groups had first time, where they studied basic shapes such as square, rectangle, triangle, and circle.

For the first group of students, the teacher had to prepare several models of cube, cuboid, pyramid and roller. When processing the squares and paragons, it starts from the cuboid and the cube. The pupils must first notice all the cubes, which have equal flat surfaces, and then connect the tips of the four mathes (toothpicks) so that they get the shape of one side of the cube. In the same way, students adopt the concept of rectangles using a cuboid model, the concept of a triangle using a pyramid model, the concept of a circle using a roller model. Finally, students see objects in the shape of squares, rectangles, triangles, and circles in the immediate vicinity.

The second group of students uses the Scratch program to detect basic geometric shapes. By pressing the corresponding key - the up, down, left and right arrows, the program draws a certain geometric shape - a red square, a blue rectangle, a green triangle, and a yellow circle, respectivly. Finally, using the Scratch quiz, students recognize different geometric shapes. This random-query query shows one of the four geometric shapes (square, rectangle, triangle, or circle), so the student should classify the geometric shape by pressing

Table 1. General school success

	M	N	S.D.	F	Sig
Traditional mode	4.67	53	0.78	0.65	0.716
Scratch programs	4.62	53	0.56		

Table 2. Achievement of students at the final test

	M	N	S.D.	F	Sig
Traditional mode	20.40 (34%)	53	11.69	6.03	0.039
Scratch programs	40.20 (67%)	53	10.16		

the corresponding key, which shows the form's name. If the student has answered / pressed correctly, then the feedback "Bravo!" Is displayed, and if it is wrong, the characteristic drum sounds of the message "No, this is (the exact name of the geometric shape)" is heard.

After learning, students have started making an online test of knowledge. The knowledge test was created on the basis of a one-dimensional Blum taxonomy, which includes six levels of achievement (Krathwohl, 2002): knowledge, understanding, application, analysis, synthesis and evaluation. The following tasks were used for testing:

1. *task at the level of knowledge* - to list basic geometric shapes
2. *task at the level of comprehension* - write which geometric form is round
3. *task at the level of application* - draw geometric shapes with four page
4. *task at the level of analysis* - indicate the similarities and differences between squares and rectangles
5. *the task at the level of synthesis* - draw a new geometric shape, consisting of three circles and three triangles
6. *task at the level of evaluation* - list examples from the environment, which resemble a circle

In the end, the results of the test were compared to determine whether there are differences in achievements between groups that have, on different ways, taught basic geometric shapes. The sample is relatively small, and the test itself is probably not well known to students if they have no experience with similar job formulations. However, these research constraints do not significantly affect the reliability and validity of the results.

RESULTS

The sample of the research consists of 106 students of the thrid grade of elementary school, of which 53 students taught basic geometric forms in a traditional way, and 53 students using the Scratch program. Out of the total number of students, 45% were boys, and 55% were girls. In order to confirm the assumption of the homogeneity of the variance between the two groups, the Levene homogeneity variance test was carried out. Since it was obtained that Sig. 0.621> p = 0.05, with this assumption confirmed. Therefore, variances in these two groups do not differ.

With ANOVE's application it was found that there are no statistically significant differences in the general school success in both groups (**Table 1**) which speaks of the equality of groups in terms of school success (F (1.58) = 0, 55, Sig. = 0.816> 0, 05).

With the help of ANOVE it was found that there is a statistically significant achievement of students in the final test between students who passed through the teaching material in a traditional manner and those who worked in the Scratch program (F (1.58) = 6.03, Sig. = 0.039 <0.05) (**Table 2**).

From the **Table 2**, it can be concluded that the second group of students has better results taking into account the maximum number of points (60) that students could have achieved on the test. So, the group, who worked in the traditional way, achieved 34% of the success, and the second group, which used Scratch programs, achieved 67% of the success. When analyzing the differences between the achievement in the final test, statistically significant differences were not found (F (1.5) = 0.69, Sig. = 0.908> 0.05).

For a more detailed insight into which tasks in the test were most successful, an analysis of the accuracy of students' responses was made. The responses are categorized as inaccurate, partly accurate and fully accurate (**Table 3** and **4**). In the case of the traditional way of working (**Table 3**), 81.55% of the students

Table 3. Accuracy of tasks in the traditional mode

	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Inaccurate	5 (4.45%)	32 (30.35%)	27 (26.00%)	65 (60.96%)	29 (27.34%)	31 (29.17%)
Partly accurate	15 (14. 00%)	/ /	48 (45.48%)	36 (31.87%)	76 (71.26%)	72 (68.30%)
Fully accurate	86 (81.55%)	74 (69.55%)	31 (33.52%)	5 (4.17%)	1 (1.40%)	3 (2.53%)

Table 4. Accuracy of tasks in the application of the Scratch program

	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Inaccurate	5 (4.45%)	11 (10.35%)	1 (1.00%)	7 (13.96%)	11 (9.17%)	19 (17.34%)
Partly accurate	4 (4. 00%)	/ /	27 (25.48%)	36 (31.87%)	39 (38.30%)	33 (31.26%)
Fully accurate	97 (91.55%)	95 (89.55%)	78 (73.52%)	57 (54.17%)	56 (52.53%)	54 (51.40%)

Table 5. Connection of general school success and achievement in final testing

		General school success
Traditional mode	Number of points at the final test	0.415*
Scratch programs	Number of points at the final test	0.310
All students	Number of points at the final test	0.356*

correctly answered the tasks at the level of knowledge, while the tasks at the level of synthesis and evaluation were successfully performed by very few students: 1.40% and 2.53%, respectively. In the case of the application of the Scratch program (**Table 4**), 91.55% of the students accurately responded to the task at the level of knowledge, while the tasks at the level of synthesis and evaluation were successfully performed by very few students: 52.53% and 51.40%, respectively.

In order to determine the link between achievement in final testing and general school success, a correlation analysis was conducted for both samples individually and in group (**Table 5**).

As can be seen from **Table 5**, in the first group of students, who learned the basics of geometry in the traditional way, the coefficient of correlation is statistically significant. Correlation for both groups is also statistically significant when considered as one group. In order to determine statistically significant differences in correlations, an analysis of the correlation coefficients between the two groups was initiated. For this, the online statistical calculator Psychometrica was used. It has been found that there are no statistically significant differences in correlation values for these two groups (Zops = 0.43 is greater than -1.96 and less than 1.96, for $p < 0.05$). Therefore, the affiliation of the group does not significantly affect the strength of the correlation between the achievements in the final test and the general school success.

DISCUSSION

Programming enables the development of 4Cs (creativity, collaboration, critical thinking and communication), which are essential for expressing digital literacy using a computer (Han et al., 2016). Many authors point out that such programming activities have a high cognitive relationship with mathematics (Palumbo, 1990; Subhi, 1999). The use of Scratch in mathematics teaching provides high efficiency in different domains such as creativity, motivation and ability to solve problems (Han et al., 2016).

The research has shown that there are statistically significant differences in the learning of basic geometric shapes between pupils, who studied in a conventional way and those who have been taught using the Scratch program. Thus, students from the other group achieved a 13% better result than students in the first group. This result is in line with research by other authors, who have dealt with similar research. Foerster (2015, 2016) points out that Scratch provides great opportunities for learning geometry. In particular, the function of game development, which is present in Scratch, allows for increased intersection and motivation for learning mathematical concepts. Pinto (2013) reported that Scratch contributes to making formal and rigorous mathematical language clearer and more intuitive.

Resnick et al. (2009) point out that when students use Scratch, they do not only learn to program, but their programming serves to teach other subjects. In addition to understanding programming and mathematical concepts, students can develop problem solving strategies, organize projects, and exchange ideas. Calder (2010) states that Scratch is a fun and easy-to-use environment for solving problems, but at the same time it is an useful and interesting programming environment for learning mathematical concepts. Quinn (2011) has explored the development of mathematical thinking skills using Scratch and has come to the conclusion that many mathematical elements are involved even in the creation of a basic Scratch project.

Calao et al. (2015) analyzes the effect of the development of computational thinking through the use of the Scratch development of mathematical skills in sixth graders of elementary education, for which a comparison was made between two groups of similar characteristics of the same grade, designating one as a control group and the other as an experimental group. The results show that there is a statistically significant gain in the understanding of mathematical knowledge in the experimental group, which received training in Scratch. This leads, therefore, to the conclusion that Scratch allows students to improve their performance in terms of mathematical processes of modeling, reasoning, problem solving and exercising.

By the reputation of Darlington (2013), Blum's taxonomy was chosen to test conceptual understanding or procedural skills within geometry. However, some authors believe that Blum's taxonomy is not a good indicator for determining the understanding of mathematical concepts (Ari, 2011). It is therefore necessary to introduce another dimension, which relates to pre-structural knowledge, single-structural, multi-structural, relationship-building and extended generalization. Nonetheless, one-dimensional Blum taxonomy was selected for ease of use.

Students, who used Scratch programs, better solved *the task at the level of knowledge*. They understood the basic concepts of geometry well, thanks to the graphic layout of geometric shapes. However, in this case, some students (4.00%) answered in part because they forgot to say one, two or three geometric shapes, and some students (4.45%) even forgot all four geometric shapes.

With the help of the Scratch program, students were better able to solve *the task at the level of comprehension*. Even 20% of students correctly answered that the circle is a geometric shape that is round. The yellow circle, drawn in Scratch, is very striking, and most students remember it well. However, despite the striking yellow color, some students (10.35%) gave the wrong answer.

The task at the level of application required students to draw out all four geometric shapes. Most students (73.52%), who used the Scratch program, drew a square and a rectangle, and only about half the students (45.48%), who studied in the traditional way, drew either a square or a rectangle. This confirms the previous results for the application of the Scratch program, because the task at the application level implies well-adopted lower levels (knowledge and understanding).

Students who used Scratch programs better solved *the task at the level of analysis* where they were asked to indicate the similarities and differences between the squares and the rectangles. This shows that these students understood the concept of a quadrilateral, as well as its elements - pages and angles. Also, students know what the similarities are, and what differences between squares and paragons.

The task at the level of synthesis required the students to draw a new geometric shape, consisting of three circles and three triangles. Students (71.26%), who studied in the traditional way, partially solved this task, drawing three circles or three triangles. In this group, only one student solved correctly the task. Even 52.53% of students using Scratch programs accurately plotted a new geometric shape of three circles and three squares.

In *the task at the level of evaluation*, the students listed examples from the environment, which resemble their appearance in a circle. Even 51.40% of students who have used Scratch programs have written more than ten examples from the environment. The students (68.30%), who studied in the traditional way, partially solved this task, since they listed three to five examples from the environment. In this group, only one student solved correctly the task.

The results of the research have shown that there are no differences in achievement between students of different sexes. So, girls and boys achieved almost the same results at the final test. This is about gender equality when it comes to learning mathematics. The finding is consistent with other studies. Ajai and Imoko (2015) have studied gender differences in mathematics achievement by using problem-based learning. The results showed that the achievements of boys and girls did not differ significantly, and that performance was a function of motivation and interest, not genders. There are different views and findings in the literature on gender and academic performance in mathematics. Brown and Kanzongo (2010) show that girls are better in all categories and areas of knowledge on a mathematical test. They have more tenness to investigate mathematical problems, but have lower mathematics self-concept than boys. Tommas et al (2016) have shown that boys performed better than girls in mathematics.

To ensure this with certainty, it is necessary to carry out more detailed analyzes and otherwise approach the research problem. In this case, the results must be taken with the reserve given that the groups had different ways of learning. The sample is relatively small, and the way the test is given to the students is probably insufficiently known, especially for students who have no experience with similar job formulations. For this reason, as well as other reasons mentioned in the previous part of the work related to mathematical knowledge testing, we need to check different approaches to checking the understanding of this topic.

The conducted research has shown that there is a connection between general school success and achievement at the final test in students who have studied geometry in a traditional way. By analyzing whether there are significant differences in the correlations between these two groups, it was found that the differences were not statistically significant, i.e. that membership of a particular group has nothing to do with it. Other research has shown a very positive relationship between students' overall and math success (Poyraz et al., 2013). Recent studies show that proficiency or success in a subject may correlate with some other subjects. For example, if a student is good at math, he / she tends to be successful in physics or computer science. Bagceci et al (2014) point out the relationship between success in English and mathematics.

CONCLUSION

The possibilities of applying Scratch in education are inexhaustible, because it is suitable for learning and developing the programming skills of creative and students in an accessible way, while also meeting the needs of today's concepts and programming modes. In addition, Scratch is a tool that can be used for any subject. It transcends its capabilities as a programming language, allowing users to create various programs for learning and checking knowledge.

Programming can be integrated everywhere in the classroom. Teaching other subjects becomes more attractive, more interesting, and learners more quickly and easily accept new concepts. Mathematics and programming are closely related to teaching, examples and tests of knowledge. The correlation between these two subjects should be maximally implemented in order to successfully master the teaching content both of the two, creating the applicable knowledge and sustainability of the same.

This paper considered the study of basic geometric shapes in a traditional way and using the Scratch program. The students achieved better results at the final testing in geometry when the lessons were realized with the help of the Scratch program. There has been a link between school success and achievement at the final test. It should be noted that students were not skilled in solving tasks, which require logical thinking and perception of differences and similarities of basic geometric shapes, leaving room for additional research related to student testing in general.

Disclosure statement

No potential conflict of interest was reported by the authors.

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