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Professional paper

TEACHING AND LEARNING MATHEMATICS SUPPORTED BY GAMES

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Abstract

Mathematical games find application in the teaching of mathematics. Mathematical games as such have been encountered early on and are applied with the aim of encouraging students to learn the subject of mathematics. Therefore, the purpose of this paper is to answer that questions of how much games are used in the teaching of mathematics, what the purpose of using mathematical games is, which games are most commonly used, and how often games are used in the teaching of mathematics. The data collection was conducted through an online questionnaire completed by seventy teachers from the lower cycle of primary education. Games, as a part of teaching mathematics, support it in every part of the lesson, encouraging students to participate more actively and inclusively, while following the rules of the game. From the processed questionnaires, it was concluded (and the hypothesis was confirmed) that the effectiveness of games in conceptual understanding of mathematics is correlated with the development of mathematical reasoning in teaching mathematics (ρ =0.763; p=0.000). It also confirmed the hypothesis that the students' preferred games depend on the location of the school (χ^2 =17.975; p=0.012).

Keywords: teaching mathematics, learning mathematics, didactical games, mathematical games

Introduction

First, let us clarify the notion of didactic games. The didactic game in pedagogical literature shows the activity of the students that brings fun and pleasure to the students as well as realizes the defined educational goals. The main difference between ordinary play (Brousseau, 1997, pp. 48–49) and between the meaning of didactic play is that ordinary play is completely free, whereas in didactic play all students have to partake. The didactic play is used to achieve educational goals, while the main purpose of the normal play is just fun and enjoyment. The didactic play has its own external management (the teacher, the rules of the game). Didactic play is the same as other didactic situations during the teaching of mathematics. The importance of play for education and its use is encountered since the time of Hellenic philosophers. Plato (427 BC – 347 BC) proposes play as a way to teach children, also Aristotle (384 BC – 322 BC) supports the need for play to be used to teach children. According to Aristotle, the most appropriate activity for children is play. The Hellenic tradition in education continued in the Roman Empire. In fact, games used in these institutions were mainly related to the physical development of students. After the fall of the Roman Empire in Western Europe, a feudal order was created where the church had a high influence on education. All education was directed towards the development of submission and obedience of students. Therefore, strict discipline was developed and used in schools where corporal punishment was present. The main teaching method was rote learning. With this way of education, games had little place. But this does not mean that play was not very important in the Middle Ages in the lives of children. In the archaeological finds of the period between the 14th and 15th centuries, dolls, figures of dogs, figures of knights and their horses, as well as various ceramic toys have been found, although the systematic use of games within school education in this era was a taboo.

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The best time for using games in education came in the Renaissance era. Instead of submission and obedience, the education of the physically and mentally developed man was preferred. The game was also used to fulfill these criteria. The teachers of the XV-XVIII century for the use of games in the teaching process were supported by JA Comenius (1592-1670), because according to him, games have a special role in the development of children and teaching should be playful and joyful. Play contributes to the cognitive, physical, social and emotional well-being of individuals, as well as helping to develop creativity and imagination. It can tune fine motor skills and physical fitness and is a set of social interactions and cooperation. Its importance is also seen from what has been recognized by the United Nations Convention on the Rights of the Child (1989) as the right of every child. JH Pestalozzi (1746–1827) also focuses on play as a way of active learning. His position is that games should be used systematically in order to achieve educational goals. In the 18th century, there is also the first research on the educational function of games known as the Pedagogical System of Games by the German pedagogue FW Fröbel (1782–1852), who is Pestalozzi's disciple. He also believed in the great educational importance of the game and recommended its use in education. The game is, according to him, the means of youth development. German philosopher and poet F. Schiller (1759–1832), found his ideals of freedom and happiness in play. He considers play as an activity that makes possible the free liberation of the human personality and thus improves one's life. Schiller also thought about the reasons for playful behavior, where according to his ideas, play is a demonstration of the excessive vital energy of people and animals. H. Spencer (1820–1903), English philosopher and pedagogue, considered child education as preparation for life. According to him, education should be done in such a way that it is joyful, active and based on the experience of children. The German psychologist and pedagogue K. Groos (1861-1946) considers play as the preparation of children for the goals and behavior of adults. The Italian teacher M. Montessori (1870-1952) based her education system on the development of children's personality by developing sensory and motor apparatus, vocabulary, writing and reading, calculation and various skills using games to a large extent. JS Bruner (1915), LS Vygotsky (1896–1934), have also written about the important place of games in teaching and learning. J. Piaget (1896–1980), J. Dewey (1859-1952) consider the game and are of the opinion that play is the link between school and life. Therefore, games should be used, instead of artificial tasks.

Mathematical games are interpreted in various ways, but Mousoulides and Sriraman (2014) have synthesized the earlier works of Harvey, Bright (1985) and Oldfield (1991) to provide a comprehensive definition of a mathematical game. The mathematical game is defined as a pedagogical activity which has specific cognitive objectives. Students must use specific mathematical knowledge to achieve the goals for the desired result during the game; the game is enjoyable and has the potential to engage the students; the game is carried out respecting clear and specific rules. The game challenges students for interactivity with the opponent, the game includes knowledge, skill, and strategy to achieve the defined goal. Many studies talk about the positive effects of mathematical games, which means that with the use of games during the teaching of mathematics, the intended goal is achieved. The only negative effect that can be is excessive engagement in the game that leads to the loss of its pedagogical effect. Onslow (1990) in his studies investigated the positive effects of games on the social interactions of children in the framework of didactic games. He is of the opinion that didactic games should be part of mathematics teaching programs using the appropriate language, symbols and materials. The children's participation must be active throughout the game, being accompanied and managed by the teacher to achieve the goals of the lesson. Games that are mentioned in many papers include playing cards, throwing dice, games prepared by the teachers themselves. As for the digital games that are widespread among children and found in the research of the last two decades, it can be seen that digital games are also widespread in the teaching of mathematics.

However, they have still not become part of our educational programs and textbooks and are rarely applied in mathematics lessons.

Research methodology and results

The game as the subject of this research has obtained the results from the data collected from the questionnaires that were completed online during the year 2023. The questionnaire was adapted from the questionnaire of Russo. J, et al (2021). The questionnaire is composed of 18 questions that include questions to collect general information about teachers such as age, work experience, and the classes where they teach. The next questions are related to the games that the teachers apply: how often, which games, their effect and for what purpose they are used. This questionnaire was completed by a total of 70 lower cycle teachers, of whom 81.4% are female, while Table 1 presents the representation of the teachers involved in this research according to age. From the table, it can be seen that middle-aged teachers are involved with a larger percentage, while the young age with a representation of only 7%.

Table 1 Representation of teachers by age

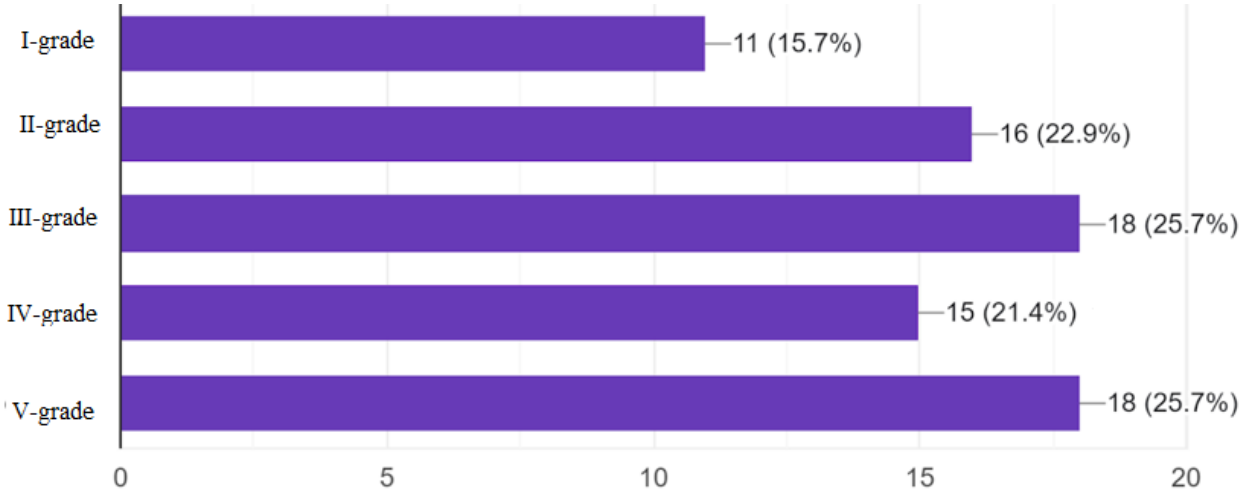
	Frequency	Percent	Valid Percent	Cumulative Percent
<29	5	7.1	7.1	7.1
30-39	16	22.9	22.9	30.0
40-49	29	41.4	41.4	71.4
50-59	17	24.3	24.3	95.7
60-67	3	4.3	4.3	100.0
Total	70	100.0	100.0	

The third question is about the location of the schools where the teachers work. Teachers working in rural schools are involved with 78.6% of the total number of teachers. Taking into account this fact, we must take into account that in our country the conditions in rural schools are different from the conditions of urban schools, because in the latter the investment is greater. The work experience of the educational staff has a great influence on the realization of the goals of the educational process, therefore this data was collected with the help of our questionnaire. This data is presented in Table 2, where it can be seen that teachers with work experience of 11-20 years and 21-30 years are more involved in this research.

Table 2. Representation of teachers according to work experience

		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Validity	<5	14	20.0	20.0	20.0
	5-10	8	11.4	11.4	31.4
	11-20	23	32.9	32.9	64.3
	21-30	17	24.3	24.3	88.6
	>30	8	11.4	11.4	100.0
	Total	70	100.0	100.0	

It is important to note that in which class of primary education are games mostly used, therefore Table 3 presents the number of teachers according to the classes where they teach. From the table we can conclude that we have almost the same representation as it belongs to the year in which the teachers are engaged. There is also a small number of teachers who work with combined classes of students (which was noted by the questionnaires).



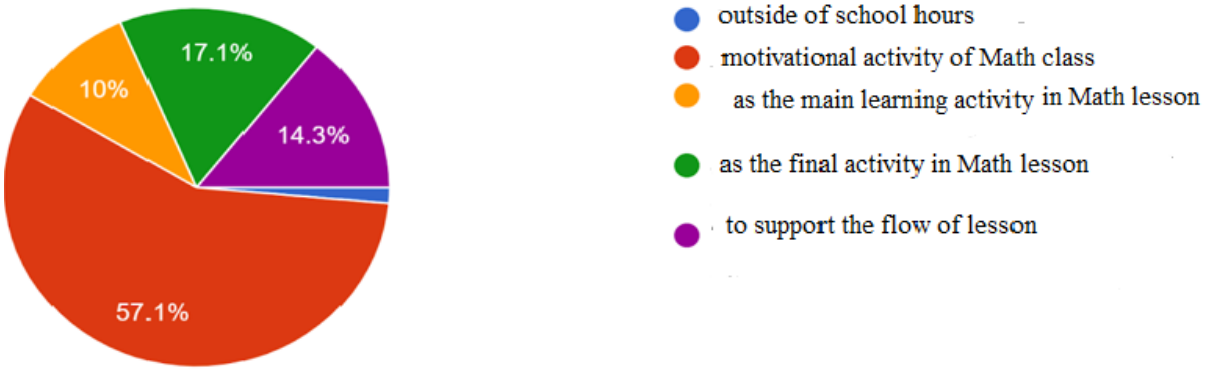
Graph.1. Representation of teachers according to the class where they teach

The sixth question of the questionnaire is how often teachers use the game in the process of teaching mathematics. Answers are scaled from 1 to 5 where 1 represents never, 2-rarely (once a month), 3-sometimes (once a week), 5-often (2-3 times a week) and 5-very often (4-5 times a week) and shown in the chart below.

Graph.2 Using the mathematical game in teaching

From the presentation above, it can be seen that most teachers often use the game in teaching mathematics. It can also be seen that there is no teacher who does not use the game to achieve the teaching objective. The other percentages of teachers, 15.7%, use it very often, while 24.3% use the game once a week. From this we can conclude that the game is quite present in the teaching of mathematics in the lower cycle of primary education in our country.

The seventh question is for what purpose or effect do teachers use the game in mathematics lessons. The answers of the teachers are presented in the following graph.



Graph.3 The purpose of using mathematical games

From the answers to the seventh question, we can easily conclude that for the majority of teachers (57.1%), the game is a means of motivation in mathematics classes.
The questionnaire used in this paper is reliable. This is proven by the value of the Cronbach Alpha coefficient (0.915) for questions Q8-Q15, which is given in Table 3 as follows.

Table 3 Cronbach's Alpha

Reliability Statistics

Cronbach's Alpha	N of Items
,915	**8**

Questions Q8-Q15 are the set of questions related to teachers' opinions about the effects of mathematical games during teaching, while teachers' answers regarding questions Q8-Q15 are given in Table 4

Table 4 Teachers' answers to questions Q8-Q15

	1	2	3	4	5	Average
Q8- Mathematical games are effective for engaging students during the lesson	1.4%	1.8%	15.7%	27.1%	52.9%	4.24
Q9- Mathematical games are effective for maximizing student engagement during the lesson	0	1.4%	24.3%	27.1%	47.1%	4.2
Q10- Mathematical games are effective for generating mathematical discussions with student participation during the lesson	0	2.9%	22.9%	38.6%	35.7%	4.0
Q11- Mathematical games are effective for focusing students on important mathematical ideas	0	5.7%	15.7%	34.3%	44.3%	4,17
Q12- Mathematical games are effective in supporting the connection between home and school	1.4%	4.3%	22.9%	41.4%	30%	3.94
Q13- Mathematical games are effective in building procedural fluency (application of procedural rules in different cases)	0	8.6%	27.1%	32.9%	31.4%	3.87
Q14- Mathematical games are effective in building conceptual understanding in students (understands, distinguishes, clarifies mathematical concepts)	0	1.4%	24.3%	34.3%	40%	4,12
Q15- Mathematical games are effective for building mathematical reasoning in students	0	2.9%	31.4%	32.9%	32.9%	4.52

As can be seen from Table 4, the answers of the teachers for questions from 8 to question 15 are scaled according to the Likert scale and that for 1- I do not agree at all to 5- I completely agree. According to the table, games in mathematics lessons are mostly used to increase effectiveness for building mathematical reasoning, which has an average value of 4.52, for

increasing students' focus on important mathematical ideas, which has an average value of 4.17. for building conceptual understanding with an average value of 4.12 and are effective in increasing student engagement during the lesson that has an average value of 4.24. From this we see that the effects of games in teaching are not few, therefore their use must be well planned so that the results are as good as possible.

Question 16 of the questionnaire of this paper is which materials (games) the teachers use most often in their classes. The processed data show that 58.6% of the total number of teachers in mathematics classes most often use dice, while 22% of teachers most often use cards prepared by themselves. From the answers to this question, it can be seen that digital games are used the least, even though these mostly develop the skills needed for this century. This century requires dexterity in the use of technology, creativity, communication, and curiosity. We do not know where the reason lies, perhaps the answer remains for a future study. But we can assume that for such games we need IT cabinet lessons that are not used in this schooling cycle. Also, the number of IT cabinets is not sufficient in our schools, teachers or students are not prepared enough for this type of teaching and learning.

Mathematical games to be used in the classroom require relevant conditions and pre-determined objectives, for this reason the teachers have expressed that the type of games they use in mathematics lessons are dependent on the teaching unit (55.7% of teachers), from the conditions at school (34.3% of teachers), while others have expressed that this depends on the prior knowledge of the students. All these conditions are part of the use of games in the classroom where mathematics is taught, but the willingness of the teacher to integrate attractive, interesting and time-consuming games that will encourage students to be curious to learn more mathematics and to believes that mathematics is part of everyday life. After processing the collected data, it was also possible to prove the hypotheses with the help of the Pearson correlation coefficient:

H_{a1} : The effectiveness of games in the conceptual understanding of mathematics is correlated with the construction of mathematical reasoning in the teaching of mathematics $\rho = 0,763, p = 0,000$

H_{a2} : The effectiveness of mathematical games for building procedural fluency is correlated with the building of conceptual understanding in students $\rho = 0,709, p = 0,000$

H_{a3} : The effectiveness of mathematical games for building procedural fluency is correlated with building mathematical reasoning among students $\rho = 0,751, p = 0,000$

H_{a4} : The effectiveness of mathematical games for generating mathematical discussions is correlated with students' focus on difficult mathematical ideas . $\rho = 0,635, p = 0,000$

Table 5 presents the obtained values of the Pearson's coefficient, from which the learning hypotheses are derived.

Table 5 Correlation table - Pearson's coefficients

		Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15
Q8	Pearson Correlation	1	,618 **	,549 **	,583 **	,291 *	,606 **	,534 **	,494 **
	Sig. (2-tailed)		,000	,000	,000	,015	,000	,000	,000
Q9	Pearson Correlation	,618 **	1	,481 **	,628 **	,346 **	,539 **	,630 **	,569 **
	Sig. (2-tailed)	,000		,000	,000	,003	,000	,000	,000
Q10	Pearson Correlation	,549 **	,481 **	1	,635 **	,458 **	,622 **	,588 **	,556 **
	Sig. (2-tailed)	,000	,000		,000	,000	,000	,000	,000
Q11	Pearson Correlation	,583 **	,628 **	,635 **	1	,540 **	,628 **	,685 **	,616 **

	Sig. (2-tailed)	,000	,000	,000		,000	,000	,000	,000
Q12	Pearson Correlation	,291 *	,346 **	,458 **	,540 **	1	,601 **	,523 **	,558 **
	Sig. (2-tailed)	,015	,003	,000	,000		,000	,000	,000
Q13	Pearson Correlation	,606 **	,539 **	,622 **	,628 **	,601 **	1	,709 **	,751 **
	Sig. (2-tailed)	,000	,000	,000	,000	,000		,000	,000
Q14	Pearson Correlation	,534 **	,630 **	,588 **	,685 **	,523 **	,709 **	1	,763 **
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000		,000
Q15	Pearson Correlation	,494 **	,569 **	,556 **	,616 **	,558 **	,751 **	,763 **	1
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000	,000	
		70	70	70	70	70	70	70	70

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

It was mentioned above that teachers are part of urban and rural schools. With the help of Table 6, it is presented how the selection of the students' games was made according to the location of the school. Hypothesis H_{a5} has also been confirmed.

Table 6 Q3*Q18 Crorostabulation

		Dice/ cards	Pencil/ paper	Orally games	Teacher cards	Commercial games	Games for everyday life	Digital games	Counting games	
Q3 schools	urban	10	0	2	0	1	0	2	0	15
	rural	31	2	0	6	0	9	3	4	55
Total		41	2	2	6	1	9	5	4	70

H_{a5} : The favorite games of students depend on the location of the school
This hypothesis has been proven since the value of $\chi^2 = 17,965 > 14,067$; $0.012 < 0.05$ is statistically reliable and presented in Tab.7

Table 7 Acquired value of χ^2

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	17,965 [a]	7	,012
Likelihood Ratio	20,457	7	,005
Linear-by-Linear Association	,875	1	,350
N of Valid Cases	70		

a. 13 cells (81.3%) have expected count less than 5. The minimum expected count is .21.

Discussions and conclusions

This paper is a presentation of the opinions of lower cycle primary school teachers on the use of games in mathematics classes. According to the results we obtained, they reveal that teachers are frequent users of mathematical games. Games, also from the collected and processed data, are mostly used as a stimulating activity in mathematics lessons, where 71% of teachers share this opinion, while 17.1% of the numbers of teachers use games as a closing activity. The most frequent games that teachers use are dice games and cards prepared by teachers. These are simple games that probably do not affect the development of mathematical understanding at all. But, given how often teachers use games, I would suggest creating a pool of games that can be used in math lessons and which will be adaptable to the math subject, age and needs of the students. Also, the type of games and their adaptation requires knowledge on the part of teachers; therefore, they must be constantly trained in this regard. For teachers-to-be, universities should also provide for this kind of preparation for teachers, including both the pedagogical aspect of using games in teaching and their ability to adapt and modify games for their teaching purposes.

Considering that we live in a time when electronic communication is part of our everyday life in every profession, it is preferable for this type of communication to exist even in the use of digital mathematical games. The cooperation would be to provide instructions and suggestions among teachers, students and parents in primary and secondary education. Communication would present a form of mathematical interactivity, which also brings effectiveness to the use of digital games during the teaching of mathematics, which is very little present in our data. Textbooks are basic aids in the process of teaching mathematics, which should be motivating according to Iljazi. T (2022); therefore, mathematical games should be part of the activities included in the textbook. Preparing teachers to use digital games/play as part of the mathematics lesson is the need of the hour, including the pedagogical and technical aspects that offer the appropriate effectiveness of games/play in the teaching process. Digital games also have disadvantages, but if they are used with a specific, planned and controlled purpose, then the negative effects can be minimized.

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