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GAMES IN MATHEMATICS INSTRUCTION

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Abstract. The paper emphasizes various aspects of mathematical games usage in mathematics instruction. Different mathematical games are discussed in accordance to the Principles of educationally-rich mathematical games. Two of them – Bingo and Tangram – are included in a primary school mathematics instruction and their impact in the instruction was assessed. The feedback we obtained indicates increased students' interest in the subject areas and motivation to learn mathematics. Guidelines for developing more effective game variations and instruction techniques are given.

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1. INTRODUCTION

Having in mind the age of primary school students and their needs, introducing games in the instruction process comes as a very useful tool in many different aspects: from encouraging and motivating students to improving their understanding of the subject material and even academic achievements. According to the current Serbian primary school mathematics curricula, there are not specified ways of student motivation. Therefore, teachers have to use other sources of ideas for improving the instruction process. One of them is designing, modifying or simply just using pre-designed mathematical games.

Mathematical games are used to improve interest in mathematics in general [1], as well as in some specific fields of mathematics: in algebra – [2], geometry – [3], etc.

Furthermore, a well nuanced use of mathematical games can bring positive effects in various aspects of the instruction process itself. For example, Prensky in [4] records cognitive changes in student behaviour in a game-based learning. Introducing games into mathematics instruction can encourage student-student and student-teacher communication and collaboration [5], thus alleviating development of students' communicational skills [6]. This can be very helpful both in developing a positive learning atmosphere and improving students' mathematical skills and achievements, which is proven in some researches, for example [7], [8]. Mathematical games help students overcome ambivalent feelings they may have about mathematical concepts and subject areas [9], which is, of course, a good starting point for motivating students.

On the other hand, if poorly planned, organized or implemented, mathematical games can bring negative effects into mathematics instruction. If

used in isolation, games are less effective at supporting learning retention compared with other engaging, student centred, but more mathematically explicit activities [10]. For that reason, special attention should be paid at the entire process of preparation and implementation of mathematical games in the instruction process. The games that teacher plans to use in the instruction should be assessed in regard of their educational potential, which will be discussed in the next chapter.

2. GAMES AS AN ADDITION TO MATHEMATICS INSTRUCTION

When assessing whether a game should be used in the instruction process, several aspects should be discussed. Among them are:

- the level of integration and interconnections between the game and mathematics,
- the level of effort students need to invest in learning the game and interpreting it in the context of the subject material,
- the danger of developing unwanted patterns of behavior like competition among students and neglecting the importance of the subject material,
- finding as many areas as possible where the game could be successfully introduced and used.

In this regard, very useful guidelines are given by Russo et. al. In [11], they introduce a set of criteria that can help a teacher in determining if a game is appropriate for the subject material and the students he/she is working with. The criteria are known as Principles of educationally-rich mathematical games [11] and deal with five areas crucial for success of the game usage in the instruction:

1. **Students are engaged**. This can be easily recognized. The teacher can notice if the students are engaged and connect tasks given within the game with the ones concerning mathematics. Such a behavior indicates that the game meets the first criterion. On the opposite, a poorly planned introduction of a game, for example excessively repeating the game just for the sake of playing it can lead to boredom [12].
2. Mathematical games should appropriately balance students' **skill** and **luck**. Activities based on luck only cannot be expected to help in improving quality of the instruction process or any of its aspects [8], and contrary – games that emphasize skills bring better students into the focus, which can be demotivating for students that are less skilled.
3. Exploring important **mathematical concepts** and practicing important skills **should be central** to the game strategy and gameplay. One should have in mind that the very nature of most of the games – competitiveness can distract students' attention from mathematical content. This, further, means that a mathematical game should have a clearly defined mathematical purpose and align with the planned mathematical goals [13].

4. **Flexibility for learning and teaching**. Though the time invested in learning rules and regulation of a game can in no circumstances be regarded as wasted, it would be very important if an already introduced game can be used for more different topics. If so, it can lead to building students' positive learning habits.
5. Mathematical games should provide opportunities for **fostering home-school connection**. If a game has this quality, it helps students widen the field of their mathematical thinking and activities to their homes.

Taking into consideration the Five principles of educationally-rich mathematical games, one can easily assess the value of a game and decide whether it is worthy to introduce it into the instruction process or not. Even if a game does not meet all the principles the teacher can modify it in order to enrich its pedagogical value. We assessed two mathematical games – Bingo and Tangram.

Bingo – students are given 5x3 tables with "randomly" inscribed numbers and a set of problems, their solutions being some of the numbers inscribed in the tables. Students solve the problems and mark their solutions in the table, Table 1. The winner is the one who marks all numbers in a column. Some examples of the problems given to students are:

Solve the equation for x: $\frac{x}{9} = 5$.

Calculate the value of the expression $|a-b|-|c|$ *for* $a = 3$, $b = -2$, $c = -5$.

Table 1: Some of the numbers are solutions of the problems

30	63	3
47	2	51
9	45	12
11	8	6
7	0	21

We evaluated the game's compliance with the Principles as follows:

Students are easily engaged – mostly complies with the principle 1. Though the game requires more skill than luck, it is obvious that the teacher can "adjust" the luck using different layouts of numbers in the tables – partially complies with the principle 2. Mathematics is in the core of the game, but students' focus can turn to competition – partially complies with the principle 3. Flexible both in regard of concepts and learners, provides opportunity for fostering home-school connection – complies with the principles 4 and 5.

Tangram – seven boards of skill. The seven pieces can be assembled to form a square: 2 large right triangles, 1 medium right triangle, 2 small right triangles, 1 square and 1 rhomboid, Figure 1.

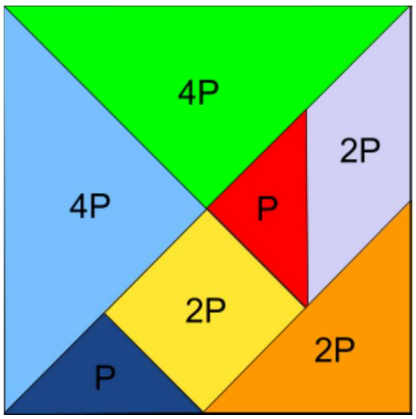

Figure 1: Tangram – seven boards of skill

Out of the pieces almost unlimited number of figures can be constructed. However, we were interested in construction of basic geometric figures – squares, rectangles, rhomboids, triangles, trapezoids. We also evaluated this game's compliance with the Principles as follows:

Students are easily engaged – complies with the principle 1. It requires more skill than luck – complies with the principle 2. Mathematics is in the core of the game – complies with the principle 3. Partially flexible in regard of concepts – mostly complies with the principle 4. Provides opportunity for fostering home-school connection – complies with the principle 5.

As a result of our assessment we came to a conclusion that these two games are appropriate for the classroom usage.

3. STUDENTS' ACTIVITIES WITH MATHEMATICAL GAMES

In May and June 2021. we organized mathematics instruction including mathematical games in "Dušan Radović" primary school in Pirot, Serbia. There were 53 students in the fifth grade (11 years old) and 55 students in the sixth grade (12 years old). Due to the limitations caused by the COVID-19 pandemics, each of the classes was divided into two groups – one of them attending the instruction in the school and the other one attending online classes. The groups interchanged weekly and a group attended either 3 classes weekly in school and one online, or vice versa.

We introduced the Bingo game in the fifth grade in the instruction on Fractions. After learning the rules of the game, students accepted it as an appropriate means in learning other topics.

In the sixth grade we used the Tangram game in the instruction on Quadrilateral and Area of triangle and quadrilateral. The students were usually given task to form a certain geometric object and explain possible transformations that lead to a simpler calculation of its area. Although the game seems to be applicable in a narrow subject area, we diversified it introducing different restrictions on number of pieces allowed or requesting different approaches.

After the games were introduced into the instruction process, we noticed several changes in the students' behaviour and learning. Students of the group exposed to the games were more active and focused on the topic. They also used to ask questions more frequently than their counterparts form the group that attended online classes, which is in line with observations in [5] and [6]. Though we noticed competitiveness among the students, it was easy to steer it in a direction that ensured faster learning and better understanding of the topic.

We also noticed that students exposed to mathematical games showed better understanding and faster learning of the topics, no matter how abstract they appeared to the students. This was observed both for understanding concepts of algebraic and geometric nature, which only confirms what was stated in [2] and [3] respectively. Another aspect of this type of instruction was an evident increase in students' motivation for learning mathematics.

All these encouraged us to continue with game-based instruction even in other areas. The fact that it was easier to imbed the Bingo game into different mathematical subjects just confirms that assessing a game's educational value according to the Principles is a right way to design, organize and implement a game-based mathematics instruction.

4. CONCLUSIONS

In order to determine if a game is worth to be introduced into the instruction, the teacher has to assess its educational and mathematical value.

It is recommended that the game complies with the Principles of educationally-rich mathematical games.

Our experience shows that such games are easily accepted among the students and make a significant impact in improving several aspects of the mathematics instruction – improves students' concentration, communication and cooperation skills, understanding subject material, etc.

On the other hand, teachers should be aware of the rise of competition among students and turning their attention off the mathematical concepts and procedures, which can altogether hinder students' mathematical development.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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