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ACHIEVEMENTS OF YOUNGER PRIMARY SCHOOL STUDENTS IN MATHEMATICS COMPETITIONS DURING IHE COVID-19 PANDEMIC[1]

Abstract: Mathematics competitions represent a very important segment of educational support to gifted students and play a significant role in identifying, motivating and working with those mathematically gifted. The COVID-19 pandemic had a strong impact on all segments of the educational process, including the implementation of mathematics classes, regular and additional, as well as the organization and implementation of mathematics competitions. In this paper we wanted to examine whether the changed conditions in which regular and additional mathematics classes were implemented had an impact on the achievement of the best-performing math students. The aim of the research is to examine the adoption of advanced level mathematical content that students should have acquired at school in the conditions of the COVID-19 pandemic. The research sample consisted of 4,064 third-grade students (school year 2020/2021) and 3,824 fourth-grade students (school year 2021/2022). The research results indicate that students who should be able to solve advanced level tasks show insufficient practice in performing the four basic calculation operations, as well as insufficient adoption of different methods of solving advanced level tasks. By looking at the achievements of the same generation of students through two consecutive competition cycles, it can be seen that insufficiently adopted concepts in the third grade during the first year of the pandemic remained unexplained in the transition to a higher grade where they represent a problem for further advancement of students.

Keywords: mathematics competitions, younger primary school students, COVID-19 pandemic, student achievement.

INTRODUCTION

In 2020, the whole world experienced a global crisis, and many countries introduced extreme measures in reaction to the spread of the coronavirus disease.

[1] The paper is the result of research conducted within the bilateral project titled "Crises, Challenges and Current Education System" realised in collaboration between the Faculty of Education in Jagodina, University of Kragujevac (Serbia) and the Faculty of Philosophy, University of Montenegro (Montenegro) (2021–2023).

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The COVID-19 pandemic led to the disruption of almost all aspects of social life, and educational systems around the world were not an exception (Mihajlović, Vulović, Maričić 2021). In March 2020, the Government of Serbia declared a state of emergency due to the COVID-19 crisis (Official Gazette 29/2020). Classes in the second semester of the academic year 2019/2020 were interrupted due to the outbreak of the pandemic and the declaration of a state of emergency (Official Gazette 30/2020) and everything was organized remotely. In school year 2020/2021, classes for students in the lower grades of primary school were realized according to a model in which students were divided into two groups. Students followed live classes in the classroom, but classes were shortened, and their number was reduced. However, the reduction in the number of classes did not apply to mathematics and mother tongue classes. On the other hand, due to the division of students into two groups and the additional workload of the teachers, there was not enough time for additional mathematics classes (either they were held rarely or not at all). In school year 2021/2022, all younger grade students returned to normal work mode.

The drastic changes due to the COVID-19 pandemic heavily influenced some crucial aspects of the organization of mathematics competitions around the world such as putting participants in the same controlled space in order to ensure equal opportunities and getting the jury together (to design tasks, control and supervise competition, and ensure proper marking) (Kenderov 2022). In order to avoid the introduced restrictions and survive, many mathematics competitions had to be organized online. In the Republic of Serbia, all mathematics competitions in the period from 2019 to 2022 were held, as planned, live but with increased epidemiological measures. Minimal shifts in the dates of the competition occurred only in the academic year 2019/2020 (Ognjanović, Hadži-Purić, Đukić 2020). Regardless of the fact that the dynamics of the competition were not disrupted, the question arose as to whether the changed conditions in which regular and additional mathematics classes were held had an impact on the best-performing math students' achievement. Some studies reported that changes in educational settings during the pandemic-affected school years had negative impacts on students' mathematical performance in general (Contini et al. 2022; Kuhfeld et al. 2022; Lewis et al. 2021; Moliner, Alegre 2022), and that lower grades were more negatively affected than higher grades (Asakawa, Ohtake 2022). Although some authors indicated that the high-achieving math students were less affected comparing to low- and average-achieving students (Schult et al. 2022), there were no studies that focused on investigating the effects of changed conditions on achievement of the best-performing math students in mathematics competitions.

With our research, we wanted to examine the effects of mathematics lessons implemented in changed conditions due to the COVID-19 pandemic on the achievements of younger primary school students in mathematics competitions.

THEORETICAL APPROACH TO THE PROBLEM

Mathematics competitions have a long tradition; they are organized in different forms, in different places and intended for different types of students. The first recorded mathematics competition dating back to 1885 was organized in Romania and included seventy students (Berinde 2004), eleven of whom received prizes (nine boys and two girls) (Kenderov 2022). In the following years, numerous countries started organizing mathematical competitions, considering them "as potentially rich opportunities for attracting young learners by proposing unusual non routine problems thus creating more opportunities for challenge they need and like" (Applebaum, Freiman 2013: 144).

Mathematical competitions represent a very important element of providing educational support to gifted students and play a significant role in the identification, motivation and support of gifted students in mathematics (Bicknell, Riley 2012; Toh 2015) and as such have a positive impact on the entire mathematics education development. Competitions provide an opportunity for students to explore new possibilities for doing mathematics that is not an integral part of the school subject of Mathematics. Such experiences allow students to apply the skills they have acquired in new situations and thus enrich their learning experience (Kenderov et al. 2009). Investigating the role of mathematics competitions in fostering students' interest in mathematics, Karnes and Riley (1996) point out that they can improve students' independent learning skills and autonomy.

Studies indicate that participation in mathematics competitions increase the likelihood that students will later have successful careers in STEM fields (Campbell, O'Connor-Petruso 2008; Steegh et al. 2019). Research shows that the first career orientations begin to form around the age of nine (Auger, Blackhurst, Wahl 2005) and continue to develop during later stages of schooling.

Regular teaching is largely based on enabling students to perform simple procedures, that is, it rarely teaches students to independently find solution methods or engage them in other mathematical processes (Lithner 2017). In a study analyzing the contents of mathematics textbooks in the USA, Australia, Canada, Finland, India, Ireland, Nepal, Scotland, Singapore, South Africa, Sweden and Tanzania, Jäder, Lithner, and Sidenwall (2015) found that 79% of tasks can be solved by applying given procedures, 13% of tasks require minor modifications of the presented solution models, and only 9% of tasks require students to construct procedures. On the other hand, solving difficult tasks that require students to have higher levels of reasoning not only generates better knowledge, but also cultivates skills for dealing with both mathematical and other types of problems (Kenderov 2022).

Mathematics competition tasks are designed to test the creativity, fluency and critical thinking of mathematically talented students. This population of students, who are the main focus of the existing literature when reporting on math-

ematics competitions (Rosolini 2011; Soifer 2012), usually expects to find among them exciting topics that they do not have the opportunity to get acquainted with in regular classes (Geogiev et al. 2008). This is the reason why the preparation of students for the competition has a significant educational impact, since by preparing for the competition, students' mathematical abilities are discovered and further developed (Kenderov 2022).

In the Republic of Serbia, the oldest, largest and best organized mathematics competitions for primary school students are organized by the Mathematical Society of Serbia (MSS). The first such competition at a republic-wide level was held in Belgrade in 1967 with the participation of 100 of the best eighth-grade students (Vulović 2016). Nowadays, it is estimated that annually close to 100,000 students from the third to the eighth grade of primary school participate in the initial levels of the competition (including the school and municipal level), while approximately thirty students reach the highest level of the national competition (Serbian Mathematical Olympiad) (Andrić et al. 2018). Students of the first and second grade of primary school are not included in mathematics competitions organized by MSS, while for the third and fourth grade primary school students, the highest level is the district competition.

RESEARCH METHODOLOGY

The research subject presented in this paper is the mathematics competitions of third and fourth grade primary school students. The problem we will look at is the achievements of the same generation of students in mathematics competitions in two consecutive school years. The competitions were organized by the Mathematical Society of Serbia and the Ministry of Education, Science and Technological Development of the Republic of Serbia. The research objective is to examine the adoption of advanced level mathematical content, which students should have acquired at school during the COVID-19 pandemic. Therefore, by analyzing the achievements of the same generation of students when they were in the third and fourth grades, we will see to what extent the knowledge was adopted during the pandemic. For the purpose of a better overview, we will base our analysis on the results of students at the municipal level of the competition. The reason for this is the degree of complexity of the tasks that are done in the municipal competition because they are the most accessible to the wider population of students. The municipal competitions taken into account were held in February 2021 and February 2022. The skills and knowledge that the students would have to demonstrate in the competition are known at the beginning of each school year and are available to all interested parties on the website of the Mathematical Society of Serbia.

The population of third grade students in the school year 2020/21 was 62,466, and the population of fourth grade students in the school year 2021/22

was 62,461 students. The competition was attended by 4,465 third grade students (7.15% of the total number of students) in the school year 2020/21, and in the school year 2021/22 there were 4,179 fourth grade students (6.69% of the total number of students).

The research sample which will be the basis for performing the analysis is given in Table 1.

Table 1. Research sample

School year	Grade	Sample size	% compared to the number of contestants	Gender	
				Male	Female
2020/21	3	4064	91.02%	2208 (54.33%)	1856 (45.67%)
2021/22	4	3824	91.51%	2101 (54.94%)	1723 (45.06%)

Research could not be conducted with the entire population since a certain number of schools did not submit students' points by tasks, but the total number only. The research instrument of both school years was a 5-task test compiled by the State Commission for the Competition of Students in Mathematics. The given tasks, solutions and method of evaluation are available at https://dms.rs/matematika-osnovne-skole/. The solutions to the tasks were evaluated partially according to a pre-defined evaluation key which all teachers who reviewed the tasks were familiar with regardless of the municipalities where the competition was held. The test time limit is 120 minutes. Data on student achievement were collected from the competition organizer's schools, MSS branches and Ministry branch units. Before the competition, the parents of all students signed an agreement to allow the processing of the results achieved by the students.

The collected data and numerical points were processed in the SPSS Statistic 20.00. Statistical measures and procedures that were used are: frequency, percentages, arithmetic mean and Mann–Whitney test.

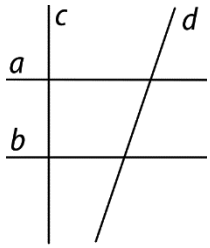
RESULTS AND DISCUSSION

In our analysis, we will first focus on the achievements of third-grade students in a competition that was organized almost a year after the declaration of the pandemic. Teaching in the period from the beginning of the pandemic to the moment of the competition was mainly organized according to a combined model (in-school and online). It is important to note at the beginning of the analysis that the students who participate in the municipal competition are the best in mathematics in the communities they come from, because in order to come to the municipal competition, it is necessary to pass one level of selection: the school competition.

Based on the educational standards for the end of the first cycle of compulsory education, observing the mutual relationships of geometric objects is at the

level of knowledge that belongs to the middle level of student achievement. The first task in the competition was aimed at observing the relationship between the lines in Figure 1. The students were asked to count how many lines are drawn in the figure and list which lines are parallel and which are normal.

Figure 1. Figure with task 1



A total of 48.23% of students did all three requirements correctly, while 5.44% of students did not do any part of the task correctly. In addition, 9.10% of the best third-grade students in the Republic of Serbia only knew how to count the lines that were given in the figure. The remaining students, in addition to listing straight lines, were able to spot, to the greatest extent, parallel lines (12.74%), while 8.76% of students listed both lines c and d as parallel. When specifying normal lines, 10.85% wrote down only one pair.

If we bear in mind that the knowledge required in this task is of fundamental importance for the further mathematical education of students, we can conclude that the level of their adoption is not satisfactory.

The second task was related to extracting the numbers of the first thousand according to a predetermined criterion. In this task, 17.62% of students did not score a single point, and the most common error in the task was writing down numbers that have the digit 2 in the place value of the hundreds, probably because the setting says that it is necessary to write down the numbers of the second hundred. In this task, 12.48% of students stopped working after writing down only one correct solution. Of the total number of students, 58.61% of them listed all 10 numbers in full, while 7.99% omitted one number when listing the numbers. The students' results in this task lead to the conclusion that students of this age need to insist more on tasks in which the solution is a set of numbers, as well as the necessity of emphasizing systematic answers in the students' work, so that they exhaust the entire set of solutions.

The third task was actually the only task in the competition in which the knowledge that is primarily acquired in additional mathematics classes is used. Magic squares appear only sporadically in mathematics textbooks, so the observation and acquisition of their properties is exclusively in these additional classes. The students' results on this task indicate that during the pandemic period in most

schools, additional mathematics classes were either absent or held at a reduced capacity, as 45.79% of students did not know how to determine a single number in the magic square out of the ten required. Although the configuration of the numbers in the magic square is given in such a way that the students can easily determine the magic sum and then by a series of additions and subtractions in the range of zero to 100 determine the numbers that need to be written in the fields of the magic square, only 26.87% of the students managed to complete the task. The other students, in the majority of cases, made calculation errors after correctly determining two or three numbers, even though the required calculation was in the range of zero to 100.

The fourth task was the combinatorial type. Based on the given numbers, the students were supposed to compose one three-digit and one two-digit number whose sum or difference is equal to the given number. Although the first part of the requirement, determining sums, had four solutions, students were asked to provide only one solution. 28.05% of students could not solve any part of the task. 71.95% of the students did the part in which addends are determined, while 41.17% did the part in which the minuend and subtrahend were determined. The fact that more than half of the students failed to put together two numbers whose difference is given indicates that combinatorial problems were probably done to a lesser extent, but also that the students are not able to systematically look at all the possibilities for the solution of the task, even though their number in the specific task is small.

The worst performed task in the competition was the fifth task in which the students were asked to add two natural numbers according to a predetermined criterion and to determine their difference. The criteria in terms of which the students had to model the numbers were related to the sum and product of the digits of the number. These concepts can be mentioned informally in regular classes, while the actual application is more done in additional classes. The findings of this task support the conclusion from the third task about the inadequacy of additional classes, since 48.62% of the best third-grade students could not determine either the smallest three-digit number with the given sum of digits, or the largest three-digit number with the given product of digits. The works of other students show that determining a three-digit number with a given product of digits was a much more difficult problem than determining a three-digit number with a given sum of digits. 33.49% of students knew how to determine only the second number, while 17.89% of students managed to determine the first number as well. It should be noted that 1.38% of students had a problem and failed to calculate the difference between these two numbers.

The average number of students' points for each task for the third grade is given in Table 2.

Table 2. Average number of points for each task in the third grade

Task	1.	2.	3.	4.	5.
Average points	15.30	13.68	7.01	11.38	6.26

In this discussion, we will also look at the achievements of students in relation to gender. The average number of students' points in relation to gender is given in Table 3.

Table 3. Average number of points for each task in relation to gender

Tasks	1.	2.	3.	4.	5.
Boys	14.90	13.74	7.12	12.10	6.35
Girls	15.78	13.61	6.89	10.53	6.16

Student scores for each task do not have a normal distribution. Through statistical testing, we can conclude that there is a statistically significant difference in the achievements of boys and girls in the first and fourth task (Table 4).

Table 4. Mann–Whitney test results by tasks

Task	1.	2.	3.	4.	5.
U	1884775.5	2029922.5	2027914	1833510	1990136
p	0.000	0.564	0.546	0.000	0.087

Girls were better at noticing geometric relationships. There is a higher percentage of boys who did not score a single point on the task (6.43%) compared to girls (3.18%), but also a higher percentage of girls who scored the maximum number of points on the task (51.72%) compared to boys (45.29%).

In the combinatorial problem in the fourth task, boys did better, because 45.43% of them managed to solve the task completely, while for girls this percentage is 36.10%. In contrast, 24.68% of boys failed to solve any part of the task, while for girls this percentage is 30.93%.

The total number of points in the municipal competition in the third grade of boys (mean of 54.20 points) and girls (mean of 52.97 points) does not have a normal distribution and we may state that there is a small but statistically significant difference ($p = 0.049$) in the total achievements between them.

The results from the competition of the same generation of students in the fourth grade can illustrate the success of students in the second year of the pandemic, when students had lessons in schools almost all the time.

The first task in the fourth grade required students to compose expressions based on the given text. A large number of students (83.42%) managed to correctly compose and calculate the value of the composed expression. However, there is a significant number of those who: did not do any part of the task correctly (1.75%); incorrectly calculated the minuend and subtrahend (9.02%); correctly calculated

both the minuend and subtrahend, but did not correctly calculate the value of the expression (5.65%). Such data indicate that a large number of students still have problems with performing basic arithmetic operations (multiplication, division and subtraction of two numbers), especially bearing in mind that the task was performed by students who were the best in mathematics in their communities.

Unlike the first task, the remaining tasks were a big problem for the students. In the second task, the students were asked to determine three unknown numbers based on the given conditions. Although the task could be solved in several ways, for example by using the longer method or by using the dependence of the sum on the change of addends, even 60.56% failed to score a single point in this task. Although 31.96% of the students did the task correctly, another 8.89% of the students went in the right direction towards the solution, but they made random mistakes in the calculation, thanks to which they did not reach the correct solution. The last data, in addition to confirming the conclusion from the first task, also indicate an unsatisfactory degree of processing of different methods of solving the task.

The problem of measuring time in the third task, although it represents the material already covered in previous grades, was the worst done task in the competition. The initial problem in the assigned task was to determine the number of days between two dates, and even 77.09% of the students failed to fulfill this requirement, and thus did not win any number of points in the task. 4.00% of students stopped after having this task done, while 11.85% of students determined how many seconds the clock would be late but not the time that the clock would show. 7.06% of students fully completed the task. As measurement and measures occupy a relatively small pool of mathematics lessons in the third and fourth grades, this task indicates that the students needed additional support to acquire this knowledge. In addition, this task was the only one in the competition in which a situation from a real environment was given, which is normally the most difficult problem type for students, so the results show that it is necessary to provide students with additional support for these types of tasks.

In the fifth task at the municipal competition for the third grade, it was observed that the students did not adopt the concept of the product of digits of a number to a satisfactory level. The same trend remained in the fourth grade as 34.23% of students failed to determine the digits used to write down the required numbers in the fourth task or to determine at least one of those numbers. About a third of the students (33.26%) managed to write down all the required numbers, but again a large percentage of students (8.55%) made mistakes when they had to add the ten obtained numbers. Bearing in mind that 32.51% of the students failed to write down all the numbers and that they made incidental mistakes in stating the required numbers, this indicates the need for a more systematic approach to the study of contents in which it is necessary to state the entire set of numbers.

The only geometric problem in the fourth grade was given in the fifth task, which was supposed to examine the extent to which the students are able to see the

perimeter of a figure as a sum of adequate constituent parts, as well as to visually notice the same parts in a given picture. As many as 76.49% of the best-performing math students of the fourth grade could not see the components of a square and a rectangle from the picture, nor could they tell by how much the perimeter of the rectangle is longer than the perimeter of the square, so they could not continue with the task. 4.26% of them noticed that the rectangle consists of 10 sides of the square, but they could not continue beyond this statement, while 5.18% of them, in addition to the mentioned statement, also noticed that the perimeter of the rectangle is greater than the perimeter of the square by the length of 6 sides of the square. Only 14.07% of students were able to finish this task, and therefore to determine the required perimeters. Although perimeter-related contents were covered in the third grade, and students had time to deepen them, continuously poor acquisition of geometric concepts during the pandemic period was noticeable.

The average number of students' points for each task for the fourth grade is given in Table 5.

Table 5. Average number of points for each task in the fourth grade

Task	1.	2.	3.	4.	5.
Average points	17.77	6.95	3.38	8.99	4.11

In relation to gender, the average number of students' points is given in Table 6.

Table 6. Average number of points for each task in relation to gender

Tasks	1.	2.	3.	4.	5.
Boys	17.67	7.14	3.68	8.94	4.38
Girls	17.89	6.71	3.02	9.06	3.79

Student scores for each task do not have a normal distribution. Through statistical testing, we can conclude that there is a statistically significant difference in the achievements of boys and girls in the third and fifth tasks, in favor of boys (Table 7).

Table 7. Mann–Whitney test results by tasks

Task	1.	2.	3.	4.	5.
U	1782693	1762212	1722228	1796554	1743762,5
p	0.214	0.107	0.001	0.683	0.020

Unlike the third grade, when the girls achieved a significantly better result than the boys, a year of working with geometric content managed not only to compensate for the difference in their achievements, but also to make the boys achieve better results in the fourth grade. Moreover, we can see that girls achieved

better results at the level of simple observation of relationships in a plane, while now, after a year, boys achieved better results at the level of applying geometric knowledge. Also, the success of boys is more evident in the area of measurements and measures for time, where 15.28% of boys did the task correctly, while the percentage of girls is 12.59%. Although the percentage of boys and girls who did parts of the task correctly is approximately the same, there is also a noticeable difference in the percentage of students who did not do any part of the task correctly (boys – 65.30%; girls – 68.60%).

Although there was a statistically significant difference in the overall achievements of girls and boys in the municipal competition in the third grade, in the fourth grade the difference in the overall achievements of boys (41.82) and girls (40.46) was larger ($p = 0.085$).

Studies show that gender differences in math achievement are not large at the beginning of schooling, but increase in later stages of education (Spelke 2005). Boys and girls at the preschool level show similar levels of mathematical literacy, but already at the level of the third grade of primary school, there are differences in achievement (Applebaum, Kondratieva, Freiman 2013; Cimpian et al. 2016). All of these can have a significant impact on later career choices in STEM fields (Hyde et al. 2008; Hyde, Mertz 2009). If we consider that the first career orientations are formed around the age of nine (Auger, Blackhurst, Wahl 2005) and that participation in math competitions can be associated with the development of a successful career in STEM fields (Campbell, O'Connor-Petruso 2008; Steegh et al. 2019), we believe that more attention should be paid to these differences.

CONCLUSION

Taking into consideration the level of considered competitions, the difficulty of the given tasks and the overall results achieved by the students, it can be concluded that the additional mathematics classes were either not sufficiently or satisfactorily implemented during the pandemic. Students who should be able to solve advanced level tasks show insufficient practice in performing the four basic calculation operations, and even with long-term practice, the students did not acquire a routine for solving calculations. Among the students, insufficient adoption of different methods of solving tasks is noticeable. Also, the students are only partially systematic in presenting their ideas, which resulted in the omission of certain parts of the solutions in the tasks of different areas. As we looked at the achievements of the same generation of students through two consecutive competition cycles, it is clearly noticeable that insufficiently adopted concepts in the third grade, in the first year of the pandemic, remained unexplained even when moving to a higher grade, where they represent a problem for the further advancement of students. This is especially noticeable in topics for which a small number of lessons were assigned.

The findings in the discussion section indicate that it is necessary to work more with students on tasks that are assigned in the context of real situations, since these types of tasks are done the worst, and this type of task is the most represented on all international student testing.

In presenting the competition results, we looked at the success of students in relation to gender. The results show that there were minimal differences in content adoption. Girls were better in the initial acquisition of basic geometric concepts, but the difference went in favor of boys with regard to the level of application in later studies. The boys were better in combinatorial problems, but also in the content for which a smaller number of classes are provided. However, one should not ignore the specific situation imposed by the pandemic during which the mathematics competitions were held. This implies that future research should address the examination of differences in student achievement in mathematics competitions in relation to gender.

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ПОСТИГНУЋА УЧЕНИКА МЛАЂИХ РАЗРЕДА ОСНОВНЕ ШКОЛЕ НА МАТЕМАТИЧКИМ ТАКМИЧЕЊИМА ТОКОМ ПАНДЕМИЈЕ КОВИДА 19

Резиме: Математичка такмичења представљају веома важан сегмент пружања образовне подршке даровитим ученицима и играју значајну улогу у идентификацији, мотивацији и раду са математички даровитима. Пандемија ковида 19 је утицала

снажно на све сегменте образовног процеса, па и на реализацију наставе математике, редовне и додатне, као и на организацију и реализацију математичких такмичења. У овом раду желели смо да испитамо да ли су измењени услови у којима су реализоване редовна и додатна настава математике имали утицај на постигнућа најбољих ученика. Циљ истраживања је испитивање усвојености математичких садржаја напредног нивоа које је требало да ученици стекну у школи у условима пандемије ковида 19. Узорак истраживања чинило је 4064 ученика трећег разреда (школске 2020/2021. године) и 3824 ученика четвртог разреда (школске 2021/2022. године). Резултати истраживања указују да ученици који би требало да решавају задатке напредног нивоа показују недовољну увежбаност извођења четири основне рачунске операције, као и недовољну усвојеност различитих метода решавања задатака напредног нивоа. Сагледавањем постигнућа исте генерације ученика кроз два узастопна такмичарска циклуса, уочава се да су недовољно усвојени концепти у трећем разреду, у првој години пандемије, остали неразјашњени и преласком у виши разред где они представљају проблем за даље напредовање ученика.

Кључне речи: математичка такмичења, млађи разреди основне школе, пандемија ковида 19, постигнућа ученика.