FACTA UNIVERSITATIS
Series: **Teaching, Learning and Teacher Education** Vol. 5, Nº2, 2021, pp. 191 - 200
https://doi.org/10.22190/FUTLTE210617015S

Professional article

EXAMPLES OF MATHEMATICAL PROBLEMS IN PRIMARY AND SECONDARY EDUCATION THAT INCLUDE THE ACTUAL CALENDAR YEAR

UDC 512.37; 511::371.3; 371.314.6:51:373.3/4

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Abstract. *It is widely believed that math classes in primary school belong into the category of least favorite classes. Entire teams of psychologists, educators and mathematicians have studied the student aversion (and, to a certain extent, parent antipathy) to math classes, but they have also studied methods and ways to overcome this problem. They have tried to find a way to improve students' activities, to make them more engaged in classes, and to increase their motivation. One of the opinions is that the student success requires their strong will, persistence, diligence and perseverance. Certainly, the competence, motivation and consistency of teachers, who-lead them to the world of knowledge, have a great influence. One of the methods of achieving a positive influence of teachers, in the domain of increasing interest in mathematics and reducing aversion to it, is the use of interesting mathematical problems, in which the numerical value of the current calendar year or even the current date appears. The aim of this paper is to point out how the motivation of primary school students to adopt mathematical content can be increased. With concrete examples of interesting algebra problems, which tickle students' fancy and make them think, we show how some lessons can be learned.*

Key words: *mathematics, student, interesting mathematical problems, teaching mathematics, motivation*

Received June 17, 2021/Accepted December 15, 2021
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1. INTRODUCTION

Even in preschool period, mathematics is presented to the children as some kind of a mild threat. Even then, mathematics becomes something different and something that is already, as a starting point, difficult. It is not exactly like that, but one of the reasons for the loss of motivation to practice mathematics might have roots in preschool period. More information on motivation in teaching mathematics can be found in (Hannula, 2006; Brophy, 2013).

If we try to understand what would draw students to mathematics, we could conclude that most of the answers are woven into the expertise and motivation of primary school teachers, mathematics teachers, secondary school teachers and, finally, professors. The most important initiator of learning in the lower grades of primary school is the teacher, because it depends on them how much students learn in school and how much each student is active in acquiring knowledge and motivated to achieve results. Therefore, "The more the teacher tries to teach their students, the more successful the students will be" (Đorđević i Đorđević, 1992, p. 19).

Education is composed of life contents, scientific contents and artistic contents. Teaching mathematics means finding harmony in that trinity. It is necessary for the teacher to take the role of a guide, and for the students to cross the indicated bridge on their own (Jovanović, 2020; Jovanović & Vukić, 2018). In the internal motivation of students, we should look for an answer to the question where their will is hidden, but their will should also be woken up and could be strengthened with interestingly presented contents, which brings us to the lecturer again. The mathematics teacher, as one of the main role models for their students, must give an example of what attitude towards work their students should have, to be objective in work and assessment, consistent and principled, so that students can properly develop and/or increase efficiency in learning mathematical content (Williams, 1993; Milanović & Novković Cvetković, 2020; Karalić et al., 2020).

As it has already been proven that there are no genetic predispositions for practicing mathematics and that the student's attitude to mathematics is largely dependent on their parents' attitude to mathematics and, in general, to education, in this paper we will give the primary role to the student-teacher interaction (Lalić-Vučetić i Mirkov, 2017). This success would be reflected in students' thorough work, their perseverance and willingness to work, which must not be short-lived. Interestingly presented mathematical problems indisputably arouse students' interest and show that the predisposition to practice mathematics is not the primary point, perhaps only the starting point from which the teacher, with their impeccable work, would disprove the thesis that someone was simply "born to study mathematics," which should remain just an excuse of those who are not willing to be interested in mathematics, and the teacher should wholeheartedly strive to invest energy and creativity in devising new ways to approach mathematical problems, so that they would be more receptive to the age group for which they are intended (Paunović i Gajtanović, 2020). Students like when they immediately receive clear and precise feedback on the solved problem (Kulik and Kulik, 1988), which explains what they did correctly and what needs to be corrected in further work. Even negative feedback regarding a mistake can act as a motive for continued engagement and more detailed work (Clifford, 1990). The most attractive are the problems that can be presented, such as panels with mathematical formulas or models of geometric shapes, which students see as a kind of reward. Stimuli and rewards, encouragement and support are as equally important when students show success in work as they are when learning difficulties occur, when motivation runs out and when work stops, because “The world of adults has a whole system of incentives such as medals, honors, charters, plaques, awards, recognitions, incentives for employees, etc.” (Nikolić, 2004, p. 23). Creativity can be a major driving force for students (Erwin, 2015), as well as the ability for students to choose problems they want to solve (Raméntol, 2011). There is more about the selection of problems, research as part of the cognition and learning process, and parts of each problem in (Vait i Gajtanović, 2017).

One of the important factors in learning process is the motivation for success, especially if it is supported by diligent and daily work. Solving tasks in which appears the number of the current year is a good way and an interesting approach to acquiring functional knowledge, whether in the text of the problem or in the solution. If the features of a given number, like determining simple factors, divisibility, sum of numbers or division of factors into subsets determined by a certain feature, were used, then combinatorial thinking will be encouraged, while joint work with students in composing tasks will certainly strengthen curiosity, need for knowledge and active learning, which are the main carriers of education in the XXI century.

2. Examples of Problems with the Calendar Year Number

Apart from preparing the content and presenting it to the students, the teacher remains aware that they are the one who will build the students’ self-confidence and try to remove the fear of mathematics and the aversion to mathematics caused by it. The student is then ready to improve their knowledge easily and acquire new knowledge. Good preparations and an interesting interpretation lead to the fact that what is learned in class will be remembered longer, and, perhaps students will eagerly solve the problems and keep them in their memory longer. With the belief that the teacher’s creativity will be in direct proportion to the will that their students will have when solving mathematical problems, as well as with a long memory of such acquired knowledge, in this paper we offer problems that will be especially interesting to students, because they will have a feeling that a mathematics class ended quickly. According to the distinguished mathematician George Polya: „… even when solving the most modest problem, if it arouses interest, if it initiates ingenuity, and if the student solves it using their own strengths, they will experience the tension and triumph of the inventor. Such experiences at an age that is accessible to impressions can create an inclination to mental work and imprint a lifelong stamp on the spirit and personality... because, once they taste the joy of mathematics, they will not forget it easily...” (Polya, 1945).

We will now list several completely new, interesting, unpublished problems, with the participation of the current year number in their formulation and/or solution, and, by solving them, students will improve their concentration, creativity, way of thinking and problem skills, and above all, strengthen the will to work and a love of mathematics.

2.1. Problems for students in lower grades of primary school

1. *The product of two different numbers of the fifth ten is equal to 2021. Determine those numbers.*

Solution: The numbers belonging to the fifth ten are 41, 42, 43…, and 50.
As the last digit of the number 2021 is 1, it can be obtained as the product of numbers whose last digits are 3 and 7. We can conclude that the numbers 43 and 47 are the solution. By multiplying 43 · 47 = 2021, we show that this solution is correct.

2. *If* $\overline{ABCD} + \overline{ABC} + \overline{AB} + \bar{A} = 2021$, *determine the digits* A, B, C *and* D.

Solution: By a simple check, we can easily conclude that A = 1 and B = 8 must hold, because otherwise the number would be greater than 2021. Now the left side of the equation is equal to 1999 $+\overline{CD} + \bar{C}$, from which, from the equation $11C + D = 22$, we obtain that $C = 2$ and $D = 0$.
By checking $1820 + 182 + 18 + 1 = 2021$, we show that this solution is correct.

3. *Determine natural numbers that have the property that their sum is equal to their product and equal to the number 2021.*

Solution: Since, by decomposing the number 2021 into factors, we get that $2021 = 1 \cdot 43 \cdot 47$, we have that

$$43 + 47 + \underbrace{1 + 1 + \cdots + 1}_{1931} = 43 \cdot 47 \cdot \underbrace{1 \cdot 1 \cdot \ldots \cdot 1}_{1931} = 2021.$$

4. *Determine the sum and product of the solution of inequality* $x < 2021$ *(*$x \in N_0$*).*

Solution: The solutions of the inequality are numbers $0,1,2, \ldots ,2020$.
Their product is equal to zero, and their sum

$$0 + 1 + 2 + 3 + \cdots + 2020 = \frac{2020 \cdot 2021}{2} = 2041210.$$

5. *If different letters correspond to different digits, and the same letters to the same digits, determine the unknown digits, so that the equations hold true:*
   a) $\overline{AAA} + \overline{ABA} + \overline{ACC} = 2021$.
   b) $\overline{ABBA} + \overline{CDC} - \bar{C} = 2021$.

Solution:

a) In order for the required sum on the left side of the equation not to be less than 180 or more than 2100, it must be true that $A = 6$.
Now $666 + \overline{6B6} + \overline{6CC} = 2021$, i.e. $\overline{10B} + \overline{11C} = 149$, from which, it is simply obtained that $B = 5$ and $C = 9$.
The obtained result is easily checked, using $666 + 656 + 699 = 2021$.

b) It is easy to see that $A = 1$ and $C = 6$ must be valid. It follows that$1000 + \overline{110B} + 1 + 600 + \overline{10D} = 2021$. From the condition that $\overline{11B} + \bar{D} = 42$ is valid, we obtain that $B = 3$ and $D = 9$.
The obtained result is easily checked, using $1331 + 696 - 6 = 2021$.

6. *Insert symbols for basic arithmetic operations and parentheses in some places of the left side of the equation* $1111111111111111111 = 2021$*, so that the equation is correct.*

Solution: We will provide two different solutions to this problem.

$$1111 + 1111 - 111 - 111 + 11 \cdot (1 + 1) - 1 = 2021$$

or

$$1111 \cdot (1 + 1 + 1) - 111 \cdot (11 + 1) + 11 + 11 - 1 - 1 = 2021.$$

In addition to their intellectual abilities, students will, by solving the following problems, adopt the following educational standards that are tested in the final exam: *MA.2.1.3. MA.3.1.1., MA.3.1.2., MA.3.1.3., MA.3.2.1. and MA.3.2.5.*

2.2. Problems for students in upper grades of primary school

1. *By how much is the sum of all proper fractions with an odd numerator and the denominator 2021 less than the sum of all proper fractions with an even numerator and the denominator 2021?*

Solution: The problem setting can be written mathematically as follows:

$$\frac{1}{2021} + \frac{3}{2021} + \cdots + \frac{2019}{2021} + x = \frac{2}{2021} + \frac{4}{2021} + \cdots + \frac{2020}{2021},$$

from where, by expressing the unknown *x* and the fact that we have 1010 addends (parentheses), we obtain

$$x = \left(\frac{2}{2021} - \frac{1}{2021}\right) + \left(\frac{4}{2021} - \frac{3}{2021}\right) + \cdots + \left(\frac{2020}{2021} - \frac{2019}{2021}\right),$$

i.e. we have that $x = \frac{1010}{2021}$.

2. *Determine the natural number n and the prime number p, so that the equation* $\frac{n}{2021} = \frac{1}{p}$ *holds true.*

Solution: Since, by decomposing the number 2021 into factors, we get that $2021 = 43 \cdot 47$, the prime number p can be one of the numbers 43 or 47, the number n is equal to 47 or 43.
So, the solutions are $n = 47$ and $p = 43$ or $n = 47$ and $p = 43$.

3. *Determine six-digit numbers of the form* $\overline{a2021b}$ *that are divisible by the number 18.*

Solution: A number is divisible by 18 if and only if it is divisible by 2 and 9. The given number will be divisible by 2 if its last digit is even, i.e. $b \in \{0,2,4,6,8\}$ while from the condition that the given number is divisible by 9, we get that it must be valid that $a + 2 + 0 + 2 + 1 + b = 5 + a + b$ is divisible by 9, i.e. that $a + b \in \{4,13\}$.
From the condition that $a + b = 4$, we obtain the following possibilities: $a = 0, b = 4$ or $a = 2, b = 2$ or $a = 4, b = 0$.

From the condition that $a+b=13$, obtain the following possibilities: $a=9, b=4$ or $a=7, b=6$ or $a=5, b=8$.
Numbers: $220212, 420210, 920214, 720216$ and 520218 are the solution.

4. *Determine digits a, b and c so that the number $\overline{a2021bc}$ is the largest possible, divisible by 12 and that all its digits are different.*

Solution: A number is divisible by 12 if it is divisible by 3 and 4. Because of the two-digit ending of the given number, we conclude that the digit c must be even, and, because of the condition of difference of digits, we have that $c \in \{4,6,8\}$, i.e. $b \in \{4,6,8\}$, from where the following possibilities are easily discerned: $b=4, c=8$ or $b=8, c=4$ or $b=6, c=4$ or $b=6, c=8$.
Since, due to the condition of divisibility by 3, it is necessary that the sum of the digits of the given number be divisible by 3, we conclude that $5+a+b+c$ must be divisible by 3. Let us consider the previous four possibilities:
For $b=4, c=8$, we have that $17+a$ should be divisible by 3, i.e. $a \in \{1,4,7\}$.
For $b=8, c=4$, we have that $17+a$ should be divisible by 3, i.e. $a \in \{1,4,7\}$.
For $b=6, c=4$, we have that $15+a$ should be divisible by 3, i.e. $a \in \{0,3,6,9\}$.
For $b=6, c=8$, we have that $19+a$ should be divisible by 3, i.e. $a \in \{2,5,8\}$.
We leave it to the reader to determine the largest of these numbers.

5. *Determine the natural number x, so that the equation $x^{2022}=x^{2021}+2021$ holds true.*

Solution: From the initial equation, we get that $x^{2022}-x^{2021}=2021$. We will consider two cases, when x is an even number and when x is an odd number.
If x is an even number, then both x^{2022} and x^{2021} are even numbers, so the left side of the equation, as the difference of two even numbers, is also an even number. This is in contrast to the fact that the odd number 2021 is on the right side.
If x is an odd number, then both x^{2022} and x^{2021} are odd numbers, so the left side of the equation, as the difference of two odd numbers, is an even number. This is in contrast to the fact that the odd number 2021 is on the right side.
Therefore, there is no natural number that satisfies the given equation.

6. *One number has been removed from a set of 10 consecutive natural numbers. If the sum of the remaining 9 numbers is equal to 2021, determine those numbers.*

Solution: Let us mark the given natural numbers with $x, x+1, x+2, \dots, x+9$, and the removed number with $x+y, 0 \leq y \leq 9$. According to the condition of the problem, it is as follows

$$x+x+1+x+2+\cdots+x+9-(x+y)=2021,$$

from where we get that $9x=1976+y$. From the condition that $1976+y$ must be divisible by 9, we get that $y=4$ and that numbers 220, 221, 222, 223, 224, 226, 227, 228 and 229 are the solution.

7. *Determine the length of the unknown leg of a right triangle if the following is given:*
   a) *The length of the known leg is $a = 180\ cm$ and the length of the hypotenuse is $c = 2029\ cm$.*
   b) *The length of the known leg is $b = 2\ cm$ and the length of the hypotenuse is $c = 45\ cm$.*

Solution:

a) If we apply Pythagoras theorem $c^2 = a^2 + b^2$ to the given right triangle, we obtain that $b^2 = c^2 - a^2 = 2029^2 - 180^2$, from where, by applying the formula for calculating the difference of squares, $b^2 = (2029 - 180) \cdot (2029 + 180) = 1849 \cdot 2209 = 43^2 \cdot 47^2$, so is the length of leg b is $b = 43 \cdot 47 = 2021$.
b) Using the idea from part a), we have that $a^2 = c^2 - b^2 = 45^2 - 2^2 = 43 \cdot 47$, from where the length of unknown leg is $b = \sqrt{2021}$.

2.3. Problems for students in secondary education

1. *Determine the last digit of the number* 3^{2021}.

Solution: Let us look at the first few degrees of the number 3 to discern regularity in the repetition of the last digit. Namely, $3^1 = \mathbf{3}, 3^2 = \mathbf{9}, 3^3 = 2\mathbf{7}, 3^4 = 8\mathbf{1}, 3^5 = 24\mathbf{3}, 3^6 = 72\mathbf{9}, \ldots$ It is clear that the last digit of the degree $3^k, k \in N$, can be $3, 9, 7$ or 1 with a repetition period of 4 numbers. Based on the previous and the fact that 2021 = 4 · 505 + 1, we have that $3^{2021} = (3^4)^{505} \cdot 3$, so is the last digit of the number 3^{2021} is 3.

2. *Using*

a) *exactly 4 different degrees of the form* $2^k, k \in \{0, 1, 2, 3, \ldots, 11\}$ *and addition and subtraction operations, we should obtain the number 2021.*
b) *exactly 5 different degrees of the form* $2^k, k \in \{0, 1, 2, 3, \ldots, 11\}$ *and addition and subtraction operations, we should obtain the number 2021.*

Solution:

a) $2^{11} - 2^5 + 2^2 + 2^0 = 2021$,
b) $2^{11} - 2^4 - 2^3 - 2^1 - 2^0 = 2021$.

3. *Using exactly 8 different degrees of the form* $2^k, k \in \{0, 1, 2, 3, \ldots, 10\}$ *and the addition operation, we should obtain the number 2021.*

Solution: $2^{10} + 2^9 + 2^8 + 2^7 + 2^6 + 2^5 + 2^2 + 2^0 = 2021$.

4. *The height corresponding to the hypotenuse of a right triangle divides the hypotenuse into segments of lengths p = 43 cm and q = 47 cm. Calculate the length of height h_c.*

Solution: The height corresponding to the hypotenuse of a right triangle divides that triangle into two also right triangles that are similar to each other and similar to the given (large) right triangle. It follows from this similarity that $h_c = \sqrt{p \cdot q} = \sqrt{2021}\ cm$.

5. *Determine the number of divisors of the number* $n = 2020 \cdot 2021 \cdot 2022$.

Solution: By decomposing the factors of the number *n* into simple factors, we obtain the canonical factorization of the number $n = 2^3 \cdot 3 \cdot 5 \cdot 43 \cdot 47 \cdot 101 \cdot 337$, and we conclude that the number *n* has

$$\tau(n) = (3+1) \cdot (1+1) \cdot (1+1) \cdot (1+1) \cdot (1+1) \cdot (1+1) \cdot (1+1) = 256$$

divisors.

6. *Prove that* $\frac{1}{2!} + \frac{2}{3!} + \frac{3}{4!} + \cdots + \frac{2020}{2021!} < 1$.

Solution: We discern that each of the addends on the left side of the inequality is of the form $\frac{n}{(n+1)!}$. If we apply to each of them the formula $\frac{n}{(n+1)!} = \frac{n+1}{(n+1)!} - \frac{1}{(n+1)!}$, we get that

$$\frac{1}{2!} = \frac{2}{2!} - \frac{1}{2!}, \frac{2}{3!} = \frac{3}{3!} - \frac{1}{3!}, \frac{3}{4!} = \frac{4}{4!} - \frac{1}{4!}, \ldots, \frac{2020}{2021!} = \frac{2021}{2021!} - \frac{1}{2021!}.$$

From here, having simply arranged the denominators in each parenthesis, we get that

$\frac{1}{2!} + \frac{2}{3!} + \frac{3}{4!} + \cdots + \frac{2020}{2021!} = \left(\frac{2}{2!} - \frac{1}{2!}\right) + \left(\frac{3}{3!} - \frac{1}{3!}\right) + \left(\frac{4}{4!} - \frac{1}{4!}\right) + \cdots + \left(\frac{2021}{2021!} - \frac{1}{2021!}\right) = \left(1 - \frac{1}{2!}\right) + \left(\frac{1}{2!} - \frac{1}{3!}\right) + \left(\frac{1}{3!} - \frac{1}{4!}\right) + \cdots + \left(\frac{1}{2020!} - \frac{1}{2021!}\right) = 1 - \frac{1}{2021!} < 1$, thereby proving the given inequality.

7. *Solve the equation* $(1 + \frac{1}{x})^{x+1} = (1 + \frac{1}{2021})^{2021}$ *in set Z.*

Solution: We can write the given equation in the form $\left(\frac{x+1}{x}\right)^{x+1} = \left(\frac{2022}{2021}\right)^{2021}$. Since the successive numbers x and x + 1 are mutually prime, the fraction $\frac{x+1}{x}$ is reduced, so the fractions $\left(\frac{x+1}{x}\right)^{x+1}$ and $\left(\frac{2022}{2021}\right)^{2021}$ are as such.
The following transformations apply: $\left(\frac{x+1}{x}\right)^{x+1} = \left(\frac{-2021}{-2022}\right)^{-2021} = \left(\frac{-2022+1}{-2022}\right)^{-2022+1}$, from which it follows that $x + 1 = -2022 + 1$, so is the solution of the equation is $x = -2022$.

8. *If for a complex number z, it holds that* $z + \frac{1}{z} = 1$, *calculate* $z^{2021} + \frac{1}{z^{2021}}$.

Solution: From the condition of the problem that $z + \frac{1}{z} = 1$, by simple calculation, we get that $z^2 + \frac{1}{z^2} = -1$ and $z^3 + \frac{1}{z^3} = -2$. The initial condition $z + \frac{1}{z} = 1$ by multiplying by z becomes $z^2 - z + 1 = 0$, from where, by multiplying both sides of the equation by $z + 1$, we get that $z^3 = -1$.
Since $z^{2021} = (z^3)^{673} \cdot z^2 = -z^2$ and analogously $\frac{1}{z^{2021}} = -\frac{1}{z^2}$, we have that

$$z^{2021} + \frac{1}{z^{2021}} = -z^2 + \frac{1}{-z^2} = -\left(z^2 + \frac{1}{z^2}\right) = 1.$$

The same solution can be reached by a similar procedure:

$$z^{2021} = z^{2022} \cdot \frac{1}{z} = (z^3)^{674} \cdot \frac{1}{z} = (-1)^{674} \cdot \frac{1}{z} = \frac{1}{z} \text{ and}$$
$$\frac{1}{z^{2021}} = \frac{1}{z^{2022}} \cdot z = \frac{1}{(z^3)^{674}} \cdot z = \frac{1}{(-1)^{674}} \cdot z = z.$$

More interesting examples, to tickle the students' fancy, can be found in (Đarmati, 2006; Petrović, 2012; Stojanović, 2012), as well as in (Simjanović and Vesić, 2016; Simjanović, et al., 2014).

3. Conclusion

It is generally believed that mathematics is one of the most difficult subjects in school. This claim has particularly been instigated by students' parents, who frighten students with its content and strict teachers. Despite the initial, certainly inadequate fear of mathematics, students, even those with lower grades, appreciate this science and understand its importance for schooling and life, primarily expecting enough points in the entrance exam.

The student's interest and their creativity are certainly upgraded with unusual mathematical problems that often require thinking outside the box, engaging all the necessary attention and concentration. This easily leads to progress in learning, increasing motivation and commitment, and, every time students make an effort, it is a challenge and real satisfaction. Attention is always focused on the process of learning and cognition, and mistakes are seen as an integral part of the teaching process, the corrections of which will surely lead to absolute progress. Students will learn to *grow their own seedlings*, not just *pick flowers*.

In this paper, we use mathematical problems, in which the number of the current calendar year appears. We weaved original problems into various areas of mathematics: divisibility, determining an unknown number, decomposing a number into simple factors, solving equations and inequalities, gradation, similarity, and Pythagoras theorem, showing how interesting problems can attract and keep students' attention by turning initial motivation into a regular habit of learning and problem solving.

Acknowledgement: *This paper is financially supported by the Ministry of Education, Science and Technologicel Development of the Republic of Serbia and the Mathematical Institute of the Serbian Academy of Sciences and Arts. Also, this paper was partially realized within IMP-002 project of the Faculty of Teacher Education in Leposavić.*

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PRIMERI MATEMATIČKIH PROBLEMA U OSNOVNOM I SREDNJEŠKOLSKOM OBRAZOVANJU KOJI UKLJUČUJU AKTUELNU KALENDARSKU GODINU

Usadjeno je mišljenje da časovi matematike u osnovnoj školi spadaju u kategoriju najmanje omiljenih časova. Čitavi timovi psihologa, edukatora i matematičara proučavali su taj animozitet učenika (a u odredjenoj meri i odbojnost roditelja) prema časovima matematike, ali su takodje proučavali metode i načine za prevazilaženje ovog problema. Pokušavali su da pronadju način da podstaknu aktivnosti učenika, da ih više angažuju u nastavi i da povećaju njihovu motivaciju. Jedno od mišljenja je da je za uspeh učenika dovoljna njihova snažna volja, istrajnost i marljivost. Svakako, kompetentnost, motivacija i doslednost nastavnika, koji ih vode u svet znanja, ima veliki uticaj. Jedan od metoda za postizanje pozitivnog uticaja nastavnika, u domenu sve većeg interesovanja za matematiku i smanjenje averzije prema njoj, jeste upotreba zanimljivih zadataka, u Kojima se pojavljuje numerička vrednost tekuće kalendarske godine ili čak tekućeg datuma. Cilj ovog rada je da ukaže na to kako se može povećati motivaijc ulenika osnovnih škola za usvajanje matematičkih sadržaja. Konkretnim primerima zanimljivih problema iz algebre, koji zagolicaju učeničku maštu i podstaknu ih na razmišljanje, pokazujemo kako se mogu naučiti neke lekcije.

Ključne reči: *matematika, učenik, zanimljivi mateamtički problemi, nastava matematike, motivacija*