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CREATIVITY IN TEACHING MATHEMATICS

Abstract: Thinking about the future of education at all levels, we need to ask ourselves what qualities students need to be encouraged and how to prepare them for the challenges that tomorrow brings. Creativity has certainly been highlighted as one of the most important factors to be encouraged during the teaching process. Creative teaching methods motivate students to think, create freely and actively participate, and consequently create a pleasant teaching climate. This is also a feature of today's understanding of modern teaching and active learning. The results of some researchers point out that creativity in teaching is still not given as much importance as it should be, especially in the context of teaching mathematics, which is the basis of other scientific fields. Teaching media represent a significant contribution to raising the quality of teaching, and textual media, as the oldest among them, are still indispensable in classroom textbooks. In this context, the tasks that appear in them are especially important, and the focus of this paper are open-ended tasks that appear in textbooks in mathematics. Previous research on this issue has not gone in a direction conducive to creativity. The aim of this paper is to show the importance of creativity in teaching and the potential of open-ended tasks in response to the demand to encourage creativity in mathematics teaching.

Keywords: Creativity, Mathematics, Teaching, Open-ended tasks

Introduction

Creativity as a phenomenon in the last few decades has been placed in the focus of many scientific disciplines and is undoubtedly of great importance for future humane schools. There is no single and generally accepted definition of creativity, but many point to the use of divergent thinking, thinking "outside the box", finding new solutions, adaptability, self-actualization, originality, and flexibility (Aleinikov, Kackmeister, & Koenig, 2000; Dubovicki, 2016; Jaušovec, 1987; Prentice, 2000; Robinson, 2011; Torrance, 1981; Treffinger, 2002). George (2005, according to Koludrović, 2009) defines it as divergent thinking that leads to unconventional solutions while solving conventional tasks. Kwon, Park J. H. and Park J. S. (2006) state that it is a human ability or skill to solve problems and create new knowledge. Amabile (2013) identifies creativity as an appropriate response, product, or solution to an open-ended task and identifies three important components to the process: relevant skills, the ability to think creatively, and intriguing motivation. Bognar (2012) approaches it from a psychoanalytic, humanistic and social point of view and emphasizes its importance in realizing human potential, encouraging better teaching and the development of society itself through creative individuals.

Rački (2013) notes the lack of an adequate theory on the structure of creativity (as there are on the structure of intelligence or personality). It can be classified into domains: everyday, scientific and artistic, and people are usually not creative in all areas at the same time. He also mentions the problem of related terms (giftedness, creativity, talent, intelligence, genius…) that appear in the literature, sometimes inaccurately or as synonyms.

In the modern information world, creativity becomes much more important than accumulating knowledge and facts (Koludrović, Reić Ercegovac, 2010), "correct" answers that students need to remember. Today, computers search for information and calculate much faster and more accurately than humans will ever be able to (Grégoire, 2016; Pehkonen, 2017), so encyclopedic knowledge may not be the greatest imperative – the school has the task of teaching students how to think. According to Kadum (2011), the essence of school creativity is in discovering different solutions to a problem.

Many scientists emphasize the great importance of (creative) teachers (Kwon, Park J. H., & Park J. S., 2006; Kadum, 2011; Dubovicki, & Omićević, 2016; Grégoire, 2016; Rohaeti, Ramadan, & Fitriani, 2019), and Bognar (2008; 2012) & Matijević (2009) see the solution in encouraging creativity in the education of future teachers, stating that the didactic conception of Jan Komensky from the 17th century is inconsistent with creative processes. Only professional and creative teachers can create conditions suitable for developing creativity in students.

Since textbooks are still the most represented media in teaching, the question is how much their tasks stimulate students' creativity. This paper will particularly focus on mathematical tasks and their (non) encouragement of creativity.

Creativity in Mathematics

It is unlikely that anyone will immediately associate creativity with maths. This is supported by textbook analyses (Dubovicki, 2012), in which the share of tasks that encourage creativity was only 1.7%. Similar results are obtained by Koludrović (2009), who notices encouraging creative thinking as advice in textbooks, but not in assignments in textbooks. The reason probably lies in the perception of mathematics as a complex subject with serious content (Dubovicki, 2016) in which there are ready-made algorithms for solving tasks that students need to adopt and one solution to be reached. It is clear that students need to master certain mathematical skills and strategies. However, this approach (characteristic of traditional teaching) should not dominate teaching because, in this way, students are insufficiently prepared for challenges outside school – education ends with acquired computing skills, but not the ability to apply these skills meaningfully (Mann, 2006).

Textbooks are more focused on teachers as a sort of manual in the organization of teaching than on students and their independent learning, and students (especially older) often perceive them as thorough, clear and useful, but also as dull and monotonous (Matijevic, Topolovcan and Rajic, 2013). Some researchers point out that textbooks are more "blindly" relied on by mathematics teachers with a completed pedagogical academy and a more extended work experience (Domović, Glasnović Gracin, Jurčec, 2012). Koludrović (2009) points out that the textbook is no longer a "learning book", but a "learn how to learn book" and that the authors should write them in accordance with the dominant social, ideological and philosophical theories to be interesting and educational.

Since textbooks are often not didactically and content-wise designed for the challenges of modern teaching, the obligation to nurture and develop creativity is directed towards teachers, but also institutions that educate future teachers. Previous textbook analyses (Koludrović, 2009; Dubovicki, 2012) show devastating results encouraging creativity in assignments.

> "A teacher in his work must not always be satisfied with the same, known and established forms of work. He must search, listen to the needs and interests of students, research and feel what is happening and find methods of initiating creative processes as well as the path for each student."
>
> (Dubovicki, Omićević, 2016, 122 – 123).

Mathematical creativity can be defined in two ways: the creation of new knowledge or the ability to flexibly solve problems (Kwon, Park J. H., Park J. S., 2006). The direction in which it will develop largely depends on teacher's approach and the tasks assigned to students. It is clear that different subjects require different efforts in showing creativity, especially if we consider the artistic group of subjects in which it is much more common, but there are some differences in creativity within the subjects themselves. The goal of mathematics should be creative thinking and, consequently, innovation in the various scientific fields on which mathematics is based. Kadum (2011) states that mathematical creativity depends on imagination, independence and intriguing motivation and is expressed in the originality of procedures, the speed of observation and problem-solving.

George (2005, according to Koludrović, & Reić Ercegovac, 2010) proposes a "Matrix of the beginnings of questions and tasks that encourage creative/divergent thinking" that corresponds to Renzulli's theory of encouraging creativity (2002), Guilford's features of divergent thinking and Bloom's taxonomy of educational goals in the cognitive field. Aspects influencing the encouragement of creativity are originality, fluency, flexibility, elaboration, curiosity, risk-taking, imagination and complexity (Dubovicki, 2016a; 2016b). Georg's categorization of questions and tasks is very useful in researching creativity in teaching because it coincides with Bloom's levels of analysis, synthesis and evaluation (Koludrović, & Reić Ercegovac, 2010).

Exploring mathematical creativity of primary school students, Rački (2013) states that a small number of children will show originality by devising evidence, but much more often, they will show flexibility in using acquired knowledge in new ways. Mathematics is specific with its set of characteristics within which it is possible to act, and activities depend on the level of knowledge and intelligence. He concludes that mathematical creativity depends on intelligence but means little without the specific mathematical knowledge acquired. Linking creativity to Piaget's theory of cognitive development, Rohaeti, Ramadan, and Fitriani (2019) conclude that students in the formal operational phase (age 11 to adulthood) achieve a slightly higher quality of creative thinking than students in the concrete operational phase (7th to 11 years). Although this research has a relatively small sample (N = 36), it indicates greater creative potential in more mature children and opens up opportunities for new research with a larger sample.

Encouraging Creativity

"Students are creative to the extent that we allow them to." (Dubovicki, Omićević, 2016, 123). Maslow (1976) argued that teaching all subjects should be more similar to art subjects that encourage creativity much more – they strengthen new types of human beings who know how to improvise, are confident and brave, autonomous and creative people.

As early as the 1960s and 1970s, Torrance (1965) proved in numerous experiments the possibility of encouraging creativity and suggested the following five principles in teaching: 1) respect for unusual issues; 2) respect imaginative and unusual ideas; 3) show children that their ideas have value; 4) provide time in which work is not evaluated and 5) combine evaluation with cause and effect. Kadum (2011, 169-170) provides similar guidelines: adapt the curriculum, as far as possible, to each student; encourage students to work independently; give students enough time for creative work because creativity is not always and immediately shown but spontaneously; divergent thinking in students should be provoked and encouraged; one should know how to listen to students, support and encourage the emergence of new and unusual ideas and answers; students should be allowed to choose and participate in decision-making (democratization of classroom work); should be adapted, if possible, to the interests and ideas of students; an atmosphere of mutual respect between students and between students and teachers should be created; criticism should be avoided (as much as possible) and one should not be afraid to start something new, different and initially uncertain.

Today we know different creative teaching methods that can be used in all teaching stages, as well as for achieving different learning outcomes. Some of them are morphological analysis, brainstorming, mind maps, six hats, guided fantasy, characters from fairy tales, cinquains, six universal questions and more (Bognar, 2012; Dubovicki, 2016; Dubovicki, & Omičević, 2016). The research results show that using creative teaching methods encourages student creativity, develops divergent thinking, a pleasant climate and student motivation (Dubovicki, & Omićević, 2016).

Grégoire (2016) believes that encouraging and developing originality requires providing ("creating") students with opportunities to work on incomplete or open-ended tasks, making mistakes and looking for more solutions to the same problem. With the development of positive emotions and intriguing motivation, they should recognize the importance of cooperation, discussion and support. As most math teaching consists of problem-solving, open-ended tasks are a way to enrich teaching and create a favourable climate for creative development. The following text states the role and importance of open-ended tasks in encouraging students' creativity in and outside the classroom (homework).

Many researchers recognize the homework of modern schools as one that teaches children to think in relation to outdated learning of encyclopedic knowledge. Homework is a learning strategy in an extracurricular context, but it is firmly defined to enable the student to learn successfully. The results of previous research (N = 538 students) show that homework is often an indicator of the (over) workload of students (Peko, Dubovicki, & Munjiza, 2014; Munjiza, Peko, & Dubovicki, 2016). The future challenges require young people who will be able to solve problems and access information rather than possess it or develop mathematical thinking rather than just computing (Pehkonen, 2017). The answer to these requirements is recognized in implementing several open-ended tasks in teaching mathematics, which includes the possibility of research, experimentation, creativity and free expression.

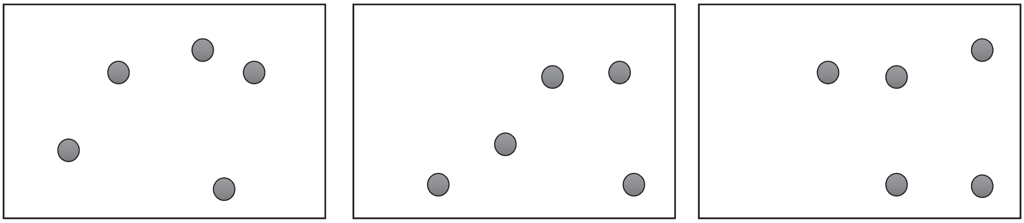
Open-ended Tasks

Shimada et al. developed open-ended tasks in Japan in the 1970s, and since then, their value has been recognized in mathematics teaching research. Unlike tasks with a unique solution and way of solving, this type of task encourages students to seek more solutions or approaches to problem-solving (Nohda, 2000; Kwon, Park J. H., Park J. S., 2006; Fujita, Kondo, Kunimune and Jones, 2014; Sabilah and Manoy, 2017), encourages different strategies for developing intellectual potential and research experiences. Their purpose is not to solve a problem but the way students come to it – to research, create, problematize, discuss and generalize. Unlike closed-ended tasks, which show what students do not know, open-ended tasks also show what they can do (Sullivan, Warren, White, & Suwarsono 1998). Each student is given the opportunity to solve the problem in the way that suits him best, which gives the opportunity to use it in heterogeneous groups.

Due to their complexity, different specific approaches are required of teachers, some of which they are not sufficiently familiar with. Wu (2000) warns against the careful use of this task since students sometimes do not distinguish guessing and experimentation from valid logical reasoning. Teachers claim (Sulivan, Clarke, & Clarke, 2013) that open-ended tasks are a problem for students who want to find solutions quickly; some students are not accustomed to tasks that "require thinking" with little guidance, risk-taking or extra effort. Piano and Hershkowitz (2008) state that teachers often have problems evaluating all students' work.

Shimada (Nohda, 2000) develops several different open mathematical problems, including the marble problem. In the examples of marbles thrown on paper, students need to decide how to determine the scatter (Picture 1) and thus determine the winner of the game. Tsubota (1988, according to Nohda, 2000) conducts classes analyzing this problem and concludes that students recognize the problem in a given situation, determine the approach to the problem, accept the diversity of solutions that carefully analyze and justify or refute. After defining the game's rules, the students tested the game with marbles and found the weaknesses of their own solutions, after which they re-analyzed and refined them.

Picture 1
Marble problem



Kwon, Park, & Park (2006) investigate the effects of implementing open-ended tasks in teaching by organizing 20 sessions in 5 high schools in Seoul. While teachers played the role of facilitator during comparisons and analyses, students were encouraged to give as many answers as possible (e.g. Picture 2). Comparing the test results with the results of the control group showed significant progress in fluency, flexibility and originality. The program developed during the research can help teachers develop students' mathematical creativity. A similar "Open Access" (OPA) framework was presented in the Munroe case study (2015) as an example of supporting teachers in teaching, contributing to their education, and creating math curricula.

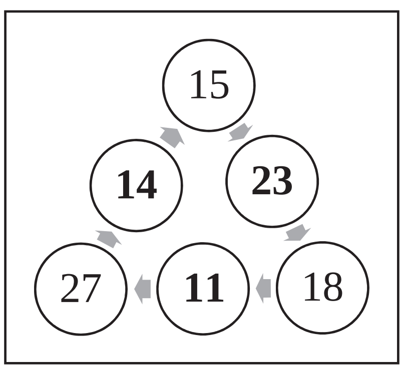
Picture 2
Example of a multiple-answer task

Among the given numbers, choose the one that is different from the others.
If possible, try to find as many different solutions as possible.

1 2 4 6 8 12

Pehkonen (2017) introduces solving the number triangle (Picture 3) into teaching as a method for perfecting computation in an unusual way. The task is to write the numbers in circles to equal the sum on each side of the triangle. Analyzing the effects of working on the number triangle during six lessons, he states that after solving simpler examples, students soon adopted rules for solving problems in the system of natural and integers and were very motivated to show their solutions and discussion.

Picture 3
Number triangle



Aziza (2017) also concludes that open-ended tasks could encourage student creativity. She explores students' oral answers to the teacher's open-ended questions about given pictures that stimulate rich discussion during class and notices great fluency (number of different answers) but somewhat less flexibility (applying different strategies), probably due to the required reaction speed by oral expression.

Here are just some of the examples in which open-ended tasks are used to encourage students' creativity, which is evident in giving more creative solutions to the same task. Additional conditions for encouraging students' creativity in this way can be obtained if we, as teachers, are creative ourselves and consider this to be desirable in teaching (Dubovicki, 2016).

Conclusion

In the hectic world we live in, a quick solution to the challenge seems to be the most important thing. Unsurprisingly, students do not cope with tasks requiring reflection, analysis, search for alternative procedures and solutions, abstract and critical thinking, and creativity – all those qualities that are expected in response to future challenges prescribed by the National Curriculum. Although there has been much talk about creativity, as well as mathematical creativity, in the last few decades, the question is how much it is truly encouraged in classrooms.

Previous research shows that the tasks of school mathematics textbooks almost always have a given algorithm, approach and solution and are therefore not suitable stimulators of mathematical creativity. Homework has proved to be an additional (over) burden for students, so in the context of homework in mathematics, it is necessary to focus on open-ended tasks that arouse curiosity and motivation in students, develop creative potential and bring original solutions. Therefore, many authors emphasize the importance of teachers as organizers of teaching processes in achieving this goal and the importance of encouraging their creativity during teacher training. Open-ended tasks have proven to be excellent promoters of creativity and a deeper understanding of mathematics and provide insight into students' ways of thinking and abilities. Many authors point out the positive results of greater implementation of such tasks in teaching, and further research in this direction would deepen understanding and give an example of good practice for encouraging creativity in teaching mathematics.

Due to the early use of modern technologies, today's generations of students who come to our primary school are often accustomed to quick solutions. As possible answer, it is necessary to create a climate in which students see the teaching of mathematics as a joy, and this is possible through the role of the teacher who often represents the personalization of the subject (Bognar, & Dubovicki, 2012). It is also desirable to use creative methods in teaching mathematics and turn the teaching of "fear" into the teaching of joy. Therefore, it is important to start with this approach in teaching mathematics as soon as possible because it is assumed that it will be an even greater challenge in the future.

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PRESCHOOL EDUCATION AND PARENT INVOLVEMENT IN CHILDREN'S ACTIVITIES AS DETERMINANTS OF STUDENTS' PERFORMANCE IN MATHEMATICS IN THE 2019 TIMSS SURVEY

Abstract: The paper uses the data obtained within the framework of the international research study for measuring the achievements of students in Mathematics and Natural Sciences (Trends in International Mathematics and Science Study) from the measurement carried out in 2019. The sample consists of a total of 3270 fourth grade students from 150 elementary schools in our country.

The paper aims to show the importance of preschool education and children's involvement in early educational activities for later progress in primary education. According to the results obtained from the study, it can be observed that students from the fourth grade have higher achievements in Mathematics if they attended kindergarten, when they had activities for the development of literacy and mathematics skills in kindergarten, or when their parents included them in activities for literacy and development of mathematics skills at an early age in the home.

The results also showed that there is a significant positive relationship between Home Resources for Learning and Early Activities. Therefore, future actions aimed at improving the achievements of our students in Mathematics on international tests should focus on creating conditions for increasing the years of stay of children in kindergarten, as well as on the time that teachers and parents devote to various activities for development. of numerical literacy and mathematical skills at home and in kindergarten.

Keywords: Preschool education and education; TIMSS; Student achievement

Introduction

TIMSS (The Trend in International Mathematics and Science Study) is an international study that measures trends in students' knowledge and abilities in mathematics and natural group subjects (physics, chemistry, biology, geography). IEA's TIMSS 2019 is the seventh assessment