PRIMARY SCHOOL STUDENTS' CREATIVE THINKING SKILLS IN MATHEMATICS

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Annotation

To develop creative thinking skills while learning mathematics in primary school, it is important to have a description of creative thinking skills and an instrument to measure these skills. The article presents: 1) a description of creative thinking skills, 2) a tool developed by the authors, empirically tested, and substantiated for measuring creative thinking skills (test), 3) the results of research analysis by groups of creative thinking skills (exploration and ideas generation; formulating questions and finding solutions) and gender.

Keywords: creative thinking skills, mathematics, primary school.

Introduction

***Relevance of the topic*.** Examining both global (European Commission, 2011; OECD, 2019; World Economic Forum, 2016) and National Education Regulations documents (Good School Concept, 2015; State Progress Strategy „Lietuva 2030", 2012) noted that it is important to empower students to creatively solve problems and think critically. It is agreed that higher-level thinking skills include the skills to adapt to a rapidly changing world, to solve constantly emerging new problems, to contribute to the creation of innovations.

The discussion on the development of higher-level thinking skills in Lithuania started in 2003-2012, analysing the results of national and international studies of students' achievements. The results of the data analysis from the Trends in International Mathematics and Science Research TIMSS 2015 report (Dukynaitė, Skripkienė, and Stundža, 2016, p. 17) show that Lithuania's 4th grade mathematics performance has been steadily improving since 2007 and, according to Trends in International Mathematics and Science Research TIMSS 2019 report (Dukynaitė and Buinevičiūtė, 2020), became statistically significantly higher than the international average. However, the biggest positive change in achievements is observed in the field of mathematics knowledge application, while changes in mathematical knowledge and mathematical thinking are limited. Curriculum specialists, researchers of student achievement, have repeatedly discussed the components of higher-level thinking skills. What are the links between creative thinking skills and students' mathematics achievements?

The scientific depth of the problem. Unfortunately, today we have relatively little data on the thinking skills of Lithuanian students. In national studies on learning outcomes, there were relatively few questions for a higher level of thinking assessment. The Lithuanian Primary Education Program (2008) the thinking skills are described quite generally, and Lithuanian teachers do not yet have descriptions of thinking skills and official examples of assessment of higher-level thinking skills.

Regarding the development of higher-level thinking skills, critical and creative thinking skills are mentioned (OECD, 2019; Krulik and Rudnick, 1993; Plubsiri and Chaiyasang, 2020) (Fig. 1). In the article we will focus on the skills of creative thinking. Defining the latter as a new and appropriate product/solution or idea.

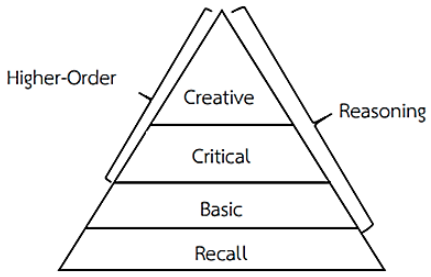

Fig. 1. Hierarchy of Thinking (Krulik and Runick, 1993, cit. by Plubsiri and Chaiyasang, 2020)

Research on creative thinking skills is also available in Lithuania. Links of creativity with intelligence and talents have been explored (Grakauskaitė-Karkockienė, 2002; Almonaitienė, 2006; Narkevičienė, 2007; Petrulytė, 2001, etc.). Intelligence in these authors' works is associated with the ability to solve problems or adapt, the ability to better understand and use abstractions, and the ability to learn. It is noted that individuals with low intelligence are rarely characterised by creativity, but high intelligence is not necessarily an indicator of creativity. Petrulytė, Beresnivičienė and Samašonok (2004) have proposed a full list of general skills of creative thinking: create new combinations of words, objects, colours, stories; to discern and create a wide range of combinations; identify missing items; create more complex combinations by drawing or constructing; see combinations of characters, numbers of objects; use language skills to create new combinations of words; summarise titles, drawings.

It is claimed that creative thinking skills can be successfully developed if students are involved in active thinking activities (Balevičienė, 2016), students are given many opportunities to test and combine various research activities and learning strategies through collaboration, offer a rich set of activities that need to solve different problems of interest to students, learn to reflect and reflect on the experience gained (Rudienė, Sičiūnienė, Bareikienė, and Uinskienė, 2015).

The problems of creative thinking development opportunities through mathematics lessons are in works of Grakauskaitė-Karkockienė, Sičiūnienė, and Strolienė (2016), Vaičiūnaitė and Sičiūnienė (2014). The researchers were also interested in the experience of Lithuanian educators and attitudes towards the development of children's creative thinking (Kondratavičienė, Sičiūnienė, Grakauskaitė-Karkockienė, and Karčauskienė, 2019) studied critical and creative thinking abilities of fourth grade students in mathematics (Kondratavičienė and Sičiūnienė, 2021). It was proposed to link higher-level thinking skills to the development of logically accurate thinking (Grabauskienė and Mockaitytė-Rastenienė, 2016; Norvaiša, 2019). Attention was drawn to the importance of the application of reading strategies in developing students' higher-level thinking skills (Sičiūnienė and Toleikytė, 2017), the adaptation of verbal and visual information to the specific needs of children in solving textual challenges (Grabauskienė and Zabulionytė, 2018).

Research Methodology

***Research problem*.** Among teachers, there is a debate about whether it is possible to develop creative thinking skills in a younger school age, especially when it comes to not only talented students. Of course, the issue of approach is very important. However, when formulating one or another approach, we need to clearly identify what is meant by showing examples of how creative thinking can be understood and interpreted at a younger school age, especially when it comes to a specific subject (in this case mathematics). Teachers do not know what creative thinking skills they should develop and how they can measure students' achievements. The concept of creative thinking skills is dynamic, changing, depending on the educational context (Beghetto, 2010; Mann, 2005). Therefore, it is important to offer the country's teachers a list of creative thinking skills when learning mathematics. It is also important to offer an instrument (test) to diagnose achievements in students' creative thinking skills.

According to the situation discussed, **the scientific problem** of the research **is** formulated: what are the components of creative thinking skills in mathematics and how to measure them? The scientific problem highlights **the research object**: primary school students' creative thinking skills and their diagnosis by teaching and learning mathematics. **The goal of the research is** to define and assess the creative thinking skills of fourth-class students by teaching and learning mathematics.

Objectives to achieve the objective of the **research**:

1. Develop a list of creative thinking skills when learning mathematics in the fourth grade.
2. Create and empirically substantiate a test to measure the creative thinking abilities of fourth-class students by teaching mathematics.
3. Discuss of fourth-class students the results of research analysis by groups of creative thinking skills and gender.

The research was based on a **modern concept of creativity.** This approach is based on the idea that everyone has creative potential, and his unfolding is not related to any field (Ivcevic and Mayer, 2006). Unlike the classical concept, this concept emphasises the social nature of creative thinking, the relationship between man and context. It is emphasised that although creative thinking can be described as a general conceptual level, the expression of

creative thinking skills differs in the subjects taught at school and depends on the general context of education (Kaufman and Beghetto, 2009).

Survey data collection methods: Analysis of scientific literature and documents, expert assessment, testing.

Methods of analysis of test data: Descriptive statistics. Kolmogorov-Smirnov test. Descriptive statistics. The data of the survey were processed using version 23 of the IBM SPSS Statistical Programmes (Statistical Package for Social Sciences). The Cronbach Alpha coefficient was calculated to verify the internal consistency of the test tasks.

***Research ethics*.** The main ethical principles of the European Code of Conduct for Research have been respected throughout the research (ALLEA, 2019): reliability; good faith; respect for colleagues, research participants and the public; responsibility for research.

According to scientists, a person can create an original mathematical idea if he perceives the relationship between mathematical elements (Silver, 1997). This is the basis of creative thinking that comes from the subconscious, when a new way of solving the problem is suddenly discovered (Mann 2005; Mak, Mak, and Mak, 2017). Creative thinking skills include inquiring, imagining, doing, reflecting (Vincent-Lancrin et al., 2019). Sternberg (1997) emphasises the ability to systematise, to analyse and to contextualise. Treffinger, Young, Selby, and Shepardson (2002) found 120 definitions of creativity and grouped them into four groups: 1) generation of ideas, 2) deepening of ideas, 3) openness and courage to explore ideas, and 4) listening to your inner voice.

Most specialists in the manifestation of creative thinking skills in mathematics rely on Guilford (1987) works, in which the basis of creative thinking is the divergent thinking, which includes four components: smoothness, flexibility, originality and detail.

Most researchers of creative thinking skills in mathematics rely on Guilford (1987) works in which creative thinking is based on divergent thinking, comprising four components: fluency, flexibility, originality, and elaboration.

Mann (2005) proposes to add to the list of creative thinking abilities to raise questions that are difficult to answer, but it is possible to answer with good thought. Emphasis is also placed on the individual's tendency to seek new connections and ideas, to improve work and share the results obtained with others (Silver, 1997; Sriraman et al., 2011).

Based on the thoughts examined by scientists, the authors of the article compiled a possible description of creative thinking abilities while learning in the fourth grade of mathematics. It also combined the wording of the description with those mentioned in the new Lithuanian Primary Education Program's project, which was submitted for consideration on the website of the Lithuanian National Education Agency (https://www.mokykla2030.lt).

Two groups of creative thinking were distinguished: exploration and ideas generation; formulating questions and finding solutions (Table 1).

Table 1

Creative Thinking Skills in Mathematics and distribution of tasks according to skills and levels of student achievement

Group of Creative Thinking skills	**Skills in Mathematics**	**Number of tasks (number of points)**		
		Satisfactory level	**Basic level**	**Higher level**
Exploration and Ideas Generation	To find sequences, set regular patterns.	1 (1)	1 (2)	
	To re-elect possible options.		1 (2)	1 (2)
	To discover the category.	1 (1)	1 (2)	
Formulating questions and finding solutions	To come up with a question (condition, task) to solve the math problem.	1 (1)	1 (2)	
	Find links between the elements in the condition.	1 (1)		
	To propose several solutions.	1 (1)	1 (2)	1 (3)
Total:		5 (5)	6 (10)	2 (5)
number of points as a percentage		25 %	50 %	25 %

Conduct of the investigation

The empirical research was conducted in two stages:

1) Preparation and validation of a research instrument (test) to measure the critical and creative thinking skills of 4th class students in mathematics.

2) Diagnostics of 4th grade students' achievements by groups of creative thinking skills and gender.

An instrument of investigation. When selecting the tasks for the test, content topics were examined not only in Lithuanian educational content documents (Lithuanian Primary Education Program, 2008; Standardized 4th grade students Mathematics Program, 2012), but also in the International Mathematics and Science Mathematics Program TIMSS (2016). The selected tasks were related to one of the two categories of creative thinking skills: exploration and ideas generation; formulating questions and finding solutions.

Prior to the test, the tasks were piloted. The process of testing the tasks allowed to see the typical mistakes made by the students, to turn some of the tasks into a closed type to suit electronic testing in a virtual learning environment. Each task and its evaluation instructions were tested in a group of 24 students, and in evaluating and considering the results obtained, modelling the target's compliance with the desired achievement level, cooperation with 3 teachers and 2 researchers was carried out.

After considering the results of the pilot test in the expert group, it was decided to model and test the test corresponding to the following parameters: the duration of the test is 45 minutes; the test consisted of 12 tasks: 2 closed type and 11 – open type; the number of points that can be scored at 20 (50 % of the task points per competency group); according to students' achievement levels, points are distributed in the following proportions: 25 % of satisfactory, 50 % basic, 25 % higher achievement levels. Further details of the test are given in Table 1.

Research impact and organisation. The sample size (N = 404) was determined using Paniotto's formula (Kardelis, 2016). When planning the empirical research, e-mails were sent to all Lithuanian primary schools. When contacting schools, it was important that all respondents participate in the survey on a voluntary basis and have equal opportunities to participate in the empirical research. The research test was conducted by the students in a virtual learning environment in Moodle.

Students' responses to closed-ended questions were evaluated by an automatic evaluation system. In line with the recommendations (Lodico, Spaulding and Voegtle, 2013), which facilitates the reliability and validity of the research, two independent, impartial external evaluators have evaluated open-ended challenges. The results of their assessment were summarised in the Percentage Agreement. 85 % of the assessments coincided, which suggests that the evaluation results are reliable.

Research Results

Numerical characteristics of the test instrument

When all the data were collected, it appeared that the students' Average grade score was 10.59 points (53.00 %). This means that the test is suitable because it is within the range of 50 % and 75 %. A Median grade score of 11.00 (55.00 %) indicates that half of the pupils have scores below or equal to 11.00 and half of the pupils scores above or equal to 11.00. Standard deviation – 4.026 (20 %) indicates the distribution of points about the average.

The internal compatibility of all tasks in the test was verified by calculating the coefficient of Cronbach alpha. Its value (0.739) demonstrates that the test task scale is reliable as a measuring instrument to assess the identified skills.

Statistical parameters for each task indicate that the tasks tested meet the requirements of this type of research and there is a correlation between the points collected for the task and the total test points (Table 2).

Table 2

Test structure analysis results

Order No:	Name of the ability corresponding to the question	Severity index	Discrimination Index	Standard deviation
1.	To find sequences, set regular patterns.	75.50 %	31.60 %	43.06 %
2.		58.04 %	35.11 %	40.51 %
3.	To re-elect possible options.	50.74 %	36.65 %	34.14 %
4.		38.37 %	41.60 %	38.11 %
5.	To discover the category.	69.80 %	36.31 %	45.97 %

6.		57.05 %	41.77 %	38.50 %
7.	To come up with a question (condition, task) to solve the math problem.	69.31 %	32.83 %	46.18 %
8.		35.02 %	42.44 %	33.30 %
9.	Find links between the elements in the condition.	39.60 %	33.98 %	48.97 %
10.	To propose several solutions.	79.21 %	34.71 %	40.63 %
11.		49.38 %	40.98 %	41.90 %
12.		49.34 %	37.71 %	41.70 %

Analysis of students' achievements by gender

As mentioned above, the test was decided by 404 students: 218 boys and 186 girls. The distribution of their points is shown in Figure 2.

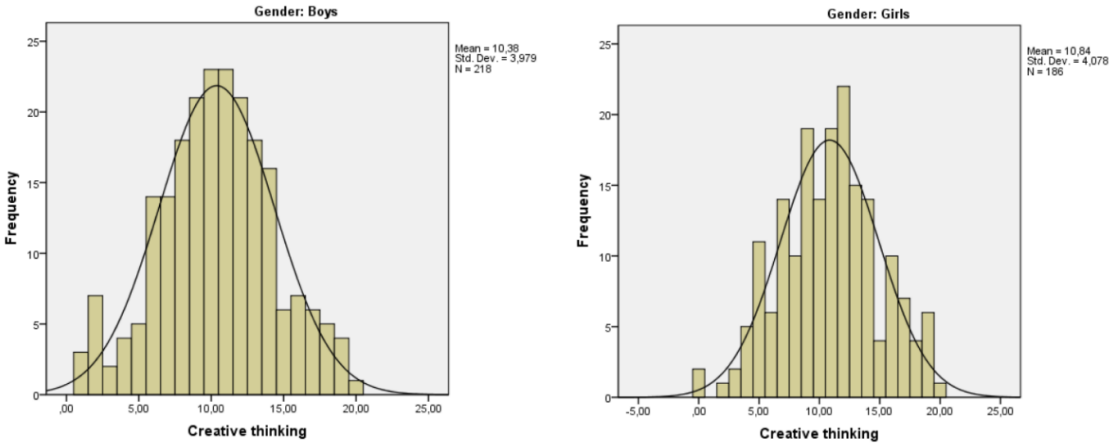

Fig. 2. Distribution of boys 'and girls' creative thinking skills test scores

The Kolmogorov-Smirnov test was used to test the hypothesis about the normality of the distribution of points collected in boys' and girls' creative thinking skills. Creative thinking skills scores for boys (W(218) = 0.059, p = 0.066) and girls (W(186) = 0.064, p = 0.064) were found to be distributed according to normal law.

When comparing the average marks for boys and girls, we see a difference in scores (see Figure 3). Hypothesis checked: H_0: an average boy's score = an average girl's score; H_1: an average boy's score ≠ an averzge girl's score. When using the student's t-test of independent groups, the difference between boys' and girls' averages of creative thinking scores was not statistically significant (t = -1.163, df = 402, p = 0.246).

Analysis of students' achievements by groups of creative thinking skills

The parameters of the research's creative thinking skills were studied by the following groups: Exploration and Ideas Generation; Formulating questions and finding solutions. Students were able to score 50 % of the points for each group of creative thinking skills. General information on the number of points collected and their dispersion is given in Table 3.

Table 3

Student's achievement analysis by groups of creative thinking skills

Group of Creative Thinking skills	Mean	Std. Deviation	Skewness	Kurtosis	First Quarter	Second Quarter (Median)	Third Quarter
Exploration and Ideas Generation	5.542	2.154	-0.075	-0.245	4.000	6.000	7.000
Formulating questions and finding solutions	5.050	2.410	-0.068	-0.719	3.000	5.000	7.000

The Kolmogorov-Smirnov test was used to test the hypothesis of the normality of the distribution of creative thinking skills. Data on the ability of exploration and idea generation (W(404) = 0.101, p = 0.000), formulating questions and finding solutions (W(404) = 0.105, p = 0,000) were found not to be distributed by normal law. For the Wilcoxon test for creative thinking skills, the difference in students' research and idea generation and searching for questions and solutions was statistically significant (Z = -4.642, p = 0.000, r = -0.230).

Analysis of students' achievements by groups of creative thinking skills and gender

Using the Kolmogorov-Smirnov test, the research found that boys' and girls' creative thinking skills are distributed according to normal law (p < 0.000). The Wilcoxon test showed that both boys (z = -2.889; p = 0.004), both among girls (z = -3.665; p = 0.000) there is no statistically significant difference in the ability to explore creative thinking and to generate ideas and search for questions and solutions.

Conclusions

1. The developed and tested instrument for measuring creative thinking skills (test) provides reliable information about the following creative thinking skills in mathematics for 4th grade students: to find sequences, set regular patterns; to re-elect possible options; to discover the category; to come up with a question (condition, task) to solve the math problem; to find links between the elements contained in the task condition; propose several solutions.
2. Was not find statistically significant difference between of 4th grade boys' and girls' creative thinking skills scores. 4th grade students are better able to research and generate ideas than to formulate questions and find solutions when learning math (the difference is statistically significant).

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