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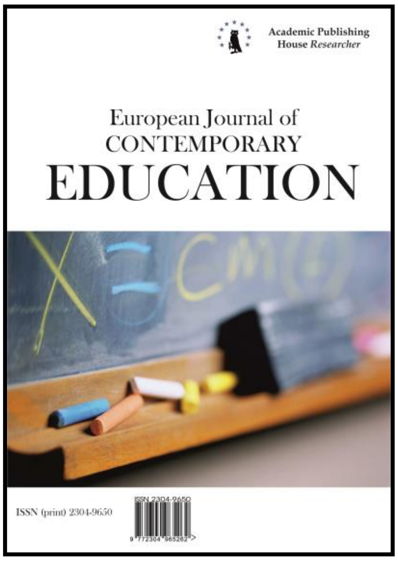


# Relationship between Mathematical Education and the Development of Creative Competencies of Students

Lýdia Kontrová [a, *], Vladimír Biba [a], Daniela Šusteková [a]

[a] Department of Quantitative Methods and Economic Informatics, University of Žilina, Slovak Republic

**Abstract**

Information and the information revolution have brought many changes to our lives. The most revolutionary is the unlimited access of most people to an incredible amount of information. Today we no longer must "keep important information and facts in our heads". With the right technology, we are always within reach. The new age also changes the nature of education. It is not necessary to remember the massive amounts of information. However, it is necessary to move the student to the position of a logical, creative subject that can effectively process, select and analyze the information obtained. As mathematics teachers, we believe that it is mathematical education that positively affects the development of student creativity. Also, the creative thinking of an individual opens the way for him to solve mathematical problems successfully. New technologies replace routine and stereotypical activities in many areas of life, not excluding mathematical activities. We believe that the human factor is irreplaceable in the area of flexible, creative and resourceful connecting of information and creation of new original ideas.

Nowadays, we believe the priority mission of teachers is to identify and develop creativity in students. One of the most significant concerns of teachers is to achieve that the mathematics develops logical thinking in students using constructivist methodologies, to make mathematics a tool to be applied to daily life. In this regard, we presume the existence of the relation between creativity and teaching of mathematics. Mathematical thinking encourages the development of creativity since it requires to make conjectures and distinguish opinions to solve a situation set out.

Our article aims to use the statistical tools to verify the hypothesis: more mathematics teaching has a significant impact on the development of students' creative potential. We expected to confirm the positive impact of mathematical education on the development of creative competences. The research was carried out on a sample of 126 students – graduates of secondary schools. To obtain the necessary data, we used the standardized Figurative Urban Creativity Test as

* Corresponding author
E-mail addresses: lydia.kontrova@fpedas.uniza.sk (L. Kontrová)

a screening tool to provide relevant insight into the creative potential of the individual. The results of the educational experiment confirmed our expectations: mathematical education has a significant impact on the development of students' creative potential.

**Keywords:** mathematical education, creative thinking, pedagogical experiment, Figurative Creativity Urban test.

## 1. Introduction

Education nowadays faces approaching technological and information revolution that fundamentally changes the way we think about the meaning, objectives and methods of teaching and learning. The fact is that the student, the citizen of the future, has available access to an almost unlimited database of information. In the future, there will be no issue to get any information, the results of scientific studies, any knowledge. It is essential to master the selection, hierarchization and creative implementation of knowledge in practice. One will not have to do the tasks of mechanical, routine and algorithmic activities; artificial intelligence can handle these instead. However, what remains irreplaceable is creative potential, innovative thinking, innovative approaches, creative problem-solving. These ideas indicate the direction of future education: great efforts must be paid to develop the creative potential of the individual. We believe that creativity is deeply rooted in many mathematical activities, and therefore mathematics education is an essential and unique platform for the formation of creative competencies of any individual. They are also critical mathematical activities such as analysis, synthesis, comparison, induction, deduction, selection, which fundamentally influence the development of students' creative potential.

The goal of mathematics education as an essential discipline to cultivate character is developing cognition and powers of thought and creativity. Similarly, Woo stated that learning mathematics paralleled performing mental gymnastics such as judgment and inference, thus teaching mathematics to include character education can lead students to exercise judgment and justice in the moral sense. These views point to the potential of mathematics instruction to inculcate not only the nature of mathematical truth but also aesthetic and moral values.

The current curriculum (educational program) for primary schools known as ISCED1 and ISCED2 places sufficient emphasis on the development of students' mathematical competencies within the educational field of Mathematics and Working with Information. Students have the subject of mathematics for 5 hours per week, which we consider sufficient to develop other competencies such as analytical, synthetic, deductive and divergent thinking skills.

The current concept of higher education in Slovakia does not favor mathematical education. There is a constant reduction in the mathematics lessons at secondary schools. While 20 years ago, 90 % of high school students attended mathematics at least three years with a minimum of 2 hours a week. Today, 70 % of students have no mathematics for more than two years at secondary schools. In the academic year 2018/19, only 12,8 % of the school graduates passed the school-leaving examination in mathematics in Slovakia. If we consider mathematics as an essential subject for developing student competence in the area of analytical, logical and creative thinking, this figure is alarming. If we consider mathematics as an essential subject for developing student competence in the area of analytical, logical and creative thinking, this figure is alarming.

## 2. Literature review

Nowadays, the request (well-known for decades) to develop and appreciate critical and creative thinking of students is becoming more and more topical. Furthermore, this is the reason why this paper deals with the development of creativity. Not only in earlier (Torrance, 1975) but also in the following resources (Zelina, 2000; Szobiová, 2004), we can find critical opinions claiming that the support of creativity in schools (also universities) has significant reserves. According to Zelina (1977), only 2 % (!) of tasks and questions asked during lessons focused on the support of creative and divergent thinking. *After all, in our everyday life, we need mainly creativity;* the author states and we have to agree with him. The stated discrepancy between the university offers and practice requirements indicates that a school does not prepare students for practice and life sufficiently. The acceptance of requirement – to develop the creative potential of students by implementation suitable study modules into study programs seems to be a necessity.

The present school of the 21st century, aligned with the metamorphoses of society, needs specific transformation. Classes can no longer act as packages of the same goods and with the same characteristics. Students are not goods to be made unified, because they are all born unique with a desire to discover new things.

Nowadays, when one cannot be sure what next year will bring, it does not need like-minded people who only know the answers to existing issues and questions. When all of us are created to the same unified image following a certain standard, the imagination and resourcefulness of people are also limited. Nevertheless, it should continue to be woken up, not fall asleep, already far in childhood.

Students are even discouraged from divergent thinking and are often afraid to express themselves and share a different opinion because they would probably say something not clever. Teachers follow the linked curriculum, which is expected of them as well. If we force students to use learned techniques for years, can innovation be expected of them? Probably not. So why isn't the opposite done?

Thinking unconventionally was not an original part of the school system. Besides, convergent thinking is also easier to assess. Sixty questions in the test are easier to evaluate than 20 questions, where students should be free to express themselves and present their thinking. If the answer is correct/incorrect, it is either correct/incorrect. It is quick and easy. With a clear answer, you have to read the text, think about it and evaluate it properly. It comes with a lot more work.

It is well known for the professional public that the term creative thinking was first introduced by scientist J.P. Guilford in a paper at a conference of the American Psychological Association in 1949. Aspects of creativity today involve several disciplines, such as psychology, pedagogy and didactics. Within the didactics of subjects taught, creativity is considered to be an activity that helps to produce new ideas. In Slovakia, the term creativity is associated mainly with the name of Miron Zelina, who analyzes and describes this term in several of his works. Creativity is an essential but complex idea to define. Though there is enormous diversity the way creativity is defined, exemplified and measured, yet there is an agreement of opinion that creativity is a significant construct of human cognition. J.P. Guilford (1949) was among the founder researchers who viewed creativity distinctively from intelligence and emphasized the role of creativity in human development. According to Guilford (Guilford, 1950) is creativity a natural resource and creativity can be studied objectively. Any effort to encourage creativity would pay high dividends to society, as cited by Runco (2014).

Definitions of creativity differ depending on various theoretical concepts, which they are based on, and are differently oriented – on personality, abilities, process and intellectual activity. Creativity is a natural trait whose development depends on the socio-cultural environment (Sillamy, 2001). It needs favourable conditions to be able to prove itself. Creativity in a potential state exists in each individual in each age. The ability of a person to clarify problems, to synthesize a previous order of elements into new contexts, to perceive an existing problem in a new way, discover new relations and produce new and untraditional views on situations are according to essential building (constituent) components of creativity (Fülöpová, 2006). The personal features of a creative personality are *tolerance towards ambiguity* and *stimulated freedom* (a creative person does not solve the problems in a traditional, generally used way). „Creativity is such interaction of a subject with an object in which the subject changes the surrounding world, creates new, useful and for a subject, referential group or population important values" (Zelina, Zelinová, 1990).

An idea is considered creative if it is original, surprising and non-routine. Creative ideas must be functional and expressive. For example, the solution to a problem is considered creative if it is new and also provides a solution to the problem. It can be considered more creative if the solution is simpler than the other previous solutions or it has a broader application or it gives a new perspective of the problem altogether. Simonton (2014) highlighted three significant perspectives to discuss creativity: the process generates a creative idea; the person who thinks and delivers a creative idea; the product which represents or communicate the creative idea.

According to Žák (2004), creativity can be understood as:

- ability to imagine or invent something new; to create solutions, ideas, thoughts by the combination, change or other use of existing ideas;
- willing attitude to accept something new, to accept a change, the courage to risk, play with thoughts and ideas and react flexibly on the newly arising situations;

• process characterized by hard work, the systematic mental activity of new ideas and solutions formation, by the space for improvisation as well as for the order and discipline. In order to clarify and accent the insistence of creative abilities of a person in the occupational performance, we will define the overview of creative abilities stated by many authors (Ďurič, Grác, 2017; Dargová, 2001) and others:

• sensitivity (problem sensitivity) – the ability to notice a problem where other people do not notice it;

• fluency – the ability to produce several ideas quickly and easily in a limited period;

• flexibility – the ability to make various solutions to problems which differ in content;

• originality – the ability to produce unusual, often witty, bright and surprising solutions and ideas;

• elaboration – the ability to solve a problem by working out the details in the solution of a problem, elegance of the solution;

• redefinition – the ability to change the meaning of an object or its part, the ability to get over the used ways of a problem solution.

Based on the stated characteristics, we can say that today many qualities of a creative personality are necessary when whatever professions are performed. For this reason, we have decided to test the rate to which the study of mathematics encourage the development of creative abilities and qualities of the students. In our article we also deal with the development of the above-mentioned components of creativity.

Mathematical thinking and creativity development

One view of mathematics is the belief that mathematics is a territory of free, innovative, inspiring, constructive and stimulating thinking. The world of mathematics is a world of constant problem-solving. Mathematical thinking has all the attributes of creative thinking. It provides students with the space to think beyond borders – even close to eternity. Mathematics is a discipline that originated in the social environment and spread throughout all civilizations, communities and cultures as a social and cultural force. It continues to evolve thanks to the passion and creativity of those remarkably brilliant mathematicians who are in love with the constant discovery of new ideas. Mathematics works with bold ideas, the synergy of the process of thinking, the power of abstraction, freedom of application and spreading ideas. All mathematical concepts are abstract, but they still systematize and explain the universe using equations and identities. It is daunting to see that the creative aspect of mathematics, as a subject in school, is often ignored or remains beyond the reach of students. Students very rarely have the opportunity to play and develop mathematical ideas, communicate mathematically or apply various solving procedures in mathematical research and develop divergent thinking. At the same time, we think that teaching mathematics can be a way to support and develop an individual's creative potential. We oppose the idea of reducing the teaching of mathematics in secondary schools and universities. The development of creative thinking is also possible with the help of a stimulating and encouraging learning environment (Runco, 1991). We think that a math teacher creating positive learning conditions promotes alternative thinking or provides an opportunity for creative dialogue to give students more than just mathematical science. He gives space and a chance for the development of creative thinking.

## 3. Materials and methods

The main goal of our research task was to answer the question, considering the previous thinking: Can we confirm the assumption that mathematical education has an essential influence on the development of the individual's creative abilities? Is it possible to verify the validity of the statement that students who devote themselves to mathematics to a greater extent are consequently more disposed in the field of creative thinking? As a result of the experiment, we expected:

Confirmation of the positive impact of teaching mathematics on the development of the creative potential of those learning (students who had more mathematics lessons per week in secondary school achieved a higher level of creative abilities tested by a standardized test of creative thinking). As part of this central subject, we looked at a set of issues that we can formulate by using questions:

- Does the type of secondary school attended have a positive effect on the level of students' creative abilities?
- Does the education of students' parents affect the level of student's creative potential?
- Do men and women differ in figural creativity?
- Will we demonstrate significant differences for selected indicators defining creative thinking (flexibility, fluency, originality, sensitivity, elaboration, the courage to experiment) in the experimental and control groups? For which indicators there is a significant positive relationship with extensive mathematical education?

We have defined the following goals for research:

1. Verify the relationship between creativity and the type of attended secondary school.
2. Verify the relationship between students' creativity and evaluation of the subject Mathematics at secondary school.
3. To verify the relationship between creativity and the number of years of mathematics absolved at high school.
4. Verify inter-sex differences concerning creativity.
5. Verify the relationship of the TSD-Z test subcategories to the type of secondary school attended and to the number of years of studying mathematics at the secondary school.

Based on the studied literature sources and previous research, we have established the following hypotheses:

H1: We assume that there will be differences in creativity among students evaluated in the subject Mathematics during secondary school by different grades.

H2: We assume that statistically significant differences in creativity will be found between students of the high and secondary vocational school students.

H3: We assume that the relationship between creativity and the number of years of learning mathematics at secondary school will be statistically significant.

H4: We assume that men and women will not differ significantly in figural creativity.

H5: We assume that the relationship between education of the students' parents and student creativity will be statistically positively significant.

H6: We assume that men and women in the individual subcategories of the TSD-Z test categories will not differ statistically significantly.

H7: We assume that students of high schools and secondary vocational schools will differ statistically significantly in individual subcategories of the TSD-Z test categories.

H8: We assume that students with different numbers of years of mathematics learning at secondary schools will differ statistically significantly in individual subcategories of categories.

H9: We assume that there will be statistically significant differences in the individual subcategories of the TSD-Z categories between students evaluated in the subject Mathematics during secondary school studies.

Description of research sample

The sample was selected randomly. It consisted of 126 students of the first year of the Faculty of PEDAS ŽU in Žilina. The respondents were graduates of various secondary schools from all over Slovakia. The selected sample consisted of 64 women and 62 men. The age of the participants ranged from 18 to 19 years. Sixty-four of them graduated in the gymnasium (secondary school) and 62 at secondary vocational school.

**Applied tool**

To get the necessary statistical data, we used the Urban's figural test of creative thinking, TSD-Z (Urban, Jellen, 1993), which meets the criteria of a culturally neutral as well knowledge-independent test. All respondents completed a short questionnaire in addition to the TSD-Z test. They answered questions about gender, the type of secondary school attended the number of years of education in the high school subject of mathematics, grades from the subject of mathematics at secondary school, education of their parents, hobbies. After completing the questionnaire and the TSD-Z test, we obtained a set of relevant data about each participant in the experiment, which allowed us to determine and verify the hypotheses.

Method of distribution, filling in and evaluation of TSD-Z test

Urban's test takes into consideration not only cognitive dimensions but also personal aspects of creativity: the complexity of perspective, the courage to take a risk, humour, emotionality, unconventionality and overcoming the barriers. According to its authors, it identifies creativity in a more sophisticated way than other performance measures. The figural test of creative thinking is a suitable screening tool that can provide an initial view of the creative potential of an individual. It is based on the principles of unfinished figures which have to be completed. There are five figures located in a frame; the sixth one is situated outside the frame (see Figure 1). Unlike traditional tests of creativity focused on the quantity (production), resp. on one of the factors of divergent thinking, a TSD-Z test takes into consideration also qualitative features of creative performances. The total score provides a general estimate of creative potential. It is an adequate tool in identifying the influences of creativity development programs in school conditions by the form of a test or retest.

The subjects are asked to complete the uncompleted drawing; somebody else had begun and finished without knowing what would come out of it, in whatever way they wish; everything is allowed and correct, they are free to draw how and whatever they wish. The test sheets are collected after completion, the latest after 15 minutes for each drawing. Figure 1 shows clean test sheets a Figure 2 shows two out of 126 drawing examples as published with our probands. The drawings were evaluated using a certified Urban test manual.

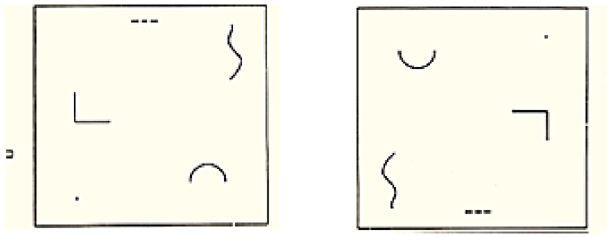

**Fig. 1.** TSD-Z sheet with no answers

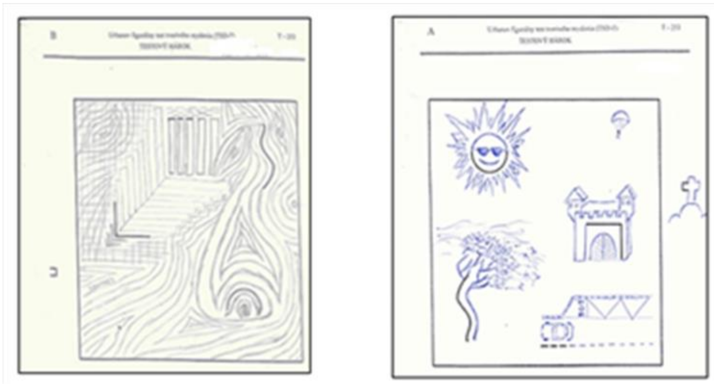

**Fig. 2**. Example of TSD-Z sheets filled in
Source: Own

Figural production is evaluated according to 14 evaluation criteria which represent the present test construct:

1. Continuations (Cn): Any use, continuation or extension of the six given figural fragments.
2. Completion (Cm): Any additions, completions, complements, supplements made to the used, continued or extended figural fragments.
3. New elements (Ne): Any new figure, symbol or element.
4. Connections made with a line (Cl) between one figural fragment or figure or another.
5. Connections made to produce a theme (Cth): Any figure contributing to a compositional theme or "gestalt".
6. Boundary breaking that is fragment dependent (Bfd): Any use, continuation or extension of the "small open square" located outside the square frame.
7. Boundary breaking that is fragment independent (Bfi).
8. Perspective (Pe): Any breaking away from two-dimensionality.

9. Humour and affectivity (Hu): Any drawing which elicits a humorous response, shows affection, emotion, or strong expressive power.

10. Unconventionality, a (Uc,a): Any manipulation of the material.

11. Unconventionality, b (Uc,b): Any surrealistic, fictional and/or abstract elements or drawings.

12. Unconventionality, c (Uc,c): Any usage of symbols or signs.

13. Unconventionality, d (Uc,d): Unconventional use of given fragments.

14. Speed (Sp): A breakdown of points, beyond a certain score-limit, according to the time spent on drawing production.

For the possibility of results comparison in an international context, we kept the original signing of individual categories. The stated criteria used during the evaluation process of each figure will provide an estimated value of the creative abilities of an individual. The result will not evaluate the quality of figural, artistic production; however, it provides the view on the willingness of a respondent to deal freely and flexibly with a submitted task. A total maximum score in a TSD-Z test is 72 points.

Weaknesses of research

First of all, it should be noted that the total sample of 126 people is not large enough to be able to generalize the results to the whole population. The results may also be affected due to the lack of motivation of the respondents to fill in. Some probands did not have to pay due attention to the test, as they were aware that they were doing it voluntarily, they can withdraw from testing at any stage, their decision will in no way affect their classification of any subject, for example. They also knew that the results would be anonymous and used for this work and that they would only know the result if they were interested. Another factor in the possible bias of the results is the potential cheating and checking the answers from a desk mate or other classmate. However, research participants were told before testing that no solution and no possibility was wrong. They knew that their task was to be more unique, original and diverse as the others. So possibly inspiring themselves by the ideas of others can ultimately put them to the lower rank. It is also impossible to rule out completely the possibility that some of the probands have already passed this test, or a similar one (for example, Torrance's test of creative thinking). Therefore, after the initial familiarization with the test and the initial instructions, they were asked to raise their hands if they did. No one has done so. If it would be the case, it is assumed that previous experience with the type of test could affect the result only to a small extent.

We worked with the gross score of the TSD-Z test. Since we performed the administration only once, we could not perform retest reliability as part of Urban's figural test of creative thinking. However, since we subsequently administered both forms of the test, we were able to use a comparison of the results of Form A and Form B to verify the reliability of the test.

Methodology

In particular, we conducted correlation research because we examined the relationships between variables. Independent variables – grade from mathematics (X1), type of secondary school (X2), number of years of mathematics at secondary school (X3), gender (X4), education of the parents (X5) and dependent variables (response variables): total creativity score (Y) and partial score Y01 – Y14 were analyzed. We were interested in partial scores in terms of evaluating the essential components of creativity, such as originality, the ability to take risks, the ability to overcome obstacles in thinking, the complexity of thinking, fluency, flexibility, redefinition. After manual evaluation of the tests, the obtained data were entered and statistically processed utilizing Mathematical Statistical Software R. Descriptive statistics was primarily used to describe the research sample and the data obtained, and primary statistical indicators such as number, mean, standard deviation, mode, range, variance, maximum and minimum were identified.

To test the effect of individual indicators (X01 to X05) on the total score obtained in the Urban test (Y), we used a two-sample t-test, as well as an analysis of variance (ANOVA).

For an application of the statistical method of ANOVA three conditions were necessary:

1. Selected samples come from basic complexes with normal division.
2. Selected samples are independent.
3. Variances of the basic complexes are equal.

The first condition, (the selected samples come from the basic sample with normal division), was verified using several normality tests as: the Shapiro–Wilk, Shapiro–Francia, Cramér–von

Mises criterion as well as using QQ – plot. Test of normality were also conducted on residuals of ANOVA models.

The second condition, (the selected samples are independent) was accomplished in relation to the construction of random variables.

For the verification of the third condition, (the variances of basic samples are equal), we used the Bartlett´s test for the equality of variances.

However, these parametric tests are no longer suitable for testing the impact of individual indicators X01 – X05 for individual sub-evaluations from the Urban test. For this reason, we used nonparametric tests: two-sample Wilcoxon or Kruskal-Wallis (KW-test) for partial scores of Y01 – Y05 and Y14.

If the sub-score has only two possible values (Y06-Y13) (see Urban test evaluation procedure), we used the population share agreement test or chi-square test of independence. However, the latter test is used for testing with larger samples, so sometimes the conditions for using it in our case are not met. We presented its results in only a few places and checked that the preconditions for its use are met here.

## 4. Results

Verification of hypothesis H1

We verified hypothesis 1 using analysis of variance for $n$ = 126, at the selected level of significance $\alpha = 0{,}05$. The results of the analysis of the variation for a grade in mathematics as an independent variable X01 and total creativity Y as a dependent (response) variable are presented in Table 1.

The resulting p-value ($p = 0{,}000021 < 0{,}01$) of expresses the probability of the error we make if we do not confirm the null hypothesis. This means that we reject the null hypothesis. We found significant differences in creativity between students evaluated in the subject of Mathematics during high school studies with various grades.

There is a strong relationship between the overall evaluation of the Urban test and the mark. The Tukey HSD test further indicates the existence of two separate groups – one consisting of students with a grade of 1 or 2, the other students with a grade of 3 or 4.

**Table 1.** Verification of hypothesis H1

| | UrbT | mark1 | mark2 | mark 3 | mark4 | test statistic | df | p-value | sgn | test |
|---|---|---|---|---|---|---|---|---|---|---|
| Y1 | Cn | 5,67 | 5,26 | 4,5 | 5,08 | 29,891 | 3 | $10^{-6}$ | *** | KW-test |
| Y2 | Cm | 5,67 | 2,23 | 4,39 | 4,94 | 29,789 | 3 | $10^{-6}$ | *** | KW-test |
| Y3 | Ne | 4,33 | 3,18 | 3,42 | 2,92 | 8,961 | 3 | 0,03 | * | KW-test |
| Y4 | Cl | 1,13 | 2,08 | 1,47 | 1,72 | 4,129 | 3 | 0,25 | | KW-test |
| Y5 | Cth | 2,73 | 2,1 | 2,22 | 2,39 | 1,176 | 3 | 0,76 | | KW-test |
| Y6 | Bfd | 4 | 3,23 | 1,17 | 0,67 | 26,01 | 3 | $10^{-5}$ | *** | chi-squared |
| Y7 | Bfi | 2,8 | 1,54 | 0,83 | 0,33 | | | | | |
| Y8 | Pe | 4,8 | 4,31 | 1,67 | 0,67 | 39,943 | 3 | $10^{-8}$ | *** | chi-squared |
| Y9 | Hu | 4 | 3,84 | 4,67 | 3,33 | | | | | |
| Y10 | Uc (a) | 1,2 | 1,31 | 1,08 | 1,25 | | | | | |
| Y11 | Uc (b) | 2 | 2,46 | 1,92 | 1 | 19,196 | 3 | 0,0002 | *** | chi-squared |
| Y12 | Uc (c) | 1,6 | 1,85 | 1,5 | 1,08 | | | | | |
| Y13 | Uc (d) | 1,6 | 2,61 | 2,25 | 2,33 | | | | | |
| Y14 | Sp | 0,67 | 0,41 | 0,86 | 0 | 15,043 | 3 | 0,002 | ** | KW- test |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Y** | **Sum** | **42,2** | **39,41** | **31,94** | **27,72** | **10,465** | **3; 48** | **$21.10^{-6}$** | *** | **ANOVA*** |
| | **sdY** | **14,6** | **9,38** | **8,01** | **10,78** | | | | | |

Note: $n$ – number of respondents; * means $p$ < 0,05; ** means $p$ < 0,01;
*** means $p$ < 0,005.

When verifying the first hypothesis, the agreement of the variances of the sample files was not confirmed. Therefore, a modification of the basic ANOVA test was used. In case of inequality of variances, R – software performs heteroskedastic F – test instead of ANOVA.

Table 1 also presents the results of statistical calculations related to the verification of hypothesis 9. We verified the hypothesis 9 in the case of categories Y1-Y5 and Y14 by Kruskal – Wallis test, within the categories Y6-Y13 we used the chi-squared test. The significance value is < 0.005 for categories Y1, Y2, Y6, Y8 and Y11. A positive relationship between grades in mathematics and the level of student creativity in the factor of complexity of thinking, overcoming borders and unconventional thinking has been confirmed. We also noted a positive correlation of $\boldsymbol{p < 0,05}$ in the area of the originality of thinking itself. On the contrary, we were surprised that the positive relationship in the field of thinking fluctuation in favor of grade 1 (also for grade 2) was not confirmed.

Verification of hypothesis H2

To verify hypothesis 2, we used one sided alternative of two-sample t-tests for the total creativity score and two sample Wilcoxon test for the sub-indicators and two proportion z-test for n = 126, at the selected significance level $\alpha = 0{,}05$.

**Table 2.** The results of the statistical tests for hypothesis H2

| | UrbT | High schools | Secondary vocational schools | test statistic | df | p-value | sgn | test |
|---|---|---|---|---|---|---|---|---|
| Y1 | Cn | 5,25 | 4,82 | 2686 | | 0,00006 | *** | Wilcoxon |
| Y2 | Cm | 5,23 | 4,68 | 2780 | | 0,00001 | *** | Wilcoxon |
| Y3 | Ne | 3,42 | 3,19 | 2233 | | 0,11 | | Wilcoxon |
| Y4 | Cl | 2 | 1,37 | 2386,5 | | 0,019 | * | Wilcoxon |
| Y5 | Cth | 2,78 | 1,79 | 2491,5 | | 0,0048 | ** | Wilcoxon |
| Y6 | Bfd | 2,62 | 1,35 | 5,434 | 1 | 0,0099 | * | 2 prop z-test |
| Y7 | Bfi | 1,69 | 0,58 | 5,806 | 1 | 0,008 | ** | 2 prop z-test |
| Y8 | Pe | 3,28 | 1,84 | 6,484 | 1 | 0,005 | ** | 2 prop z-test |
| Y9 | Hu | 4,78 | 3,1 | 9,828 | 1 | 0,00086 | *** | 2 prop z-test |
| Y10 | Uc (a) | 1,64 | 0,77 | 9,737 | 1 | 0,0009 | *** | 2 prop z-test |
| Y11 | Uc (b) | 2,16 | 1,5 | 5,454 | 1 | 0,0098 | ** | 2 prop z-test |
| Y12 | Uc (c) | 1,92 | 1,06 | 9,177 | 1 | 0,0012 | *** | 2 prop z-test |
| Y13 | Uc (d) | 2,39 | 2,23 | 0,271 | 1 | 0,3 | | 2 prop z-test |
| Y14 | Sp | 0,52 | 0,39 | 2099 | | 0,2071 | | Wilcoxon |
| **Y** | **Sum** | **39,7** | **28,7** | **6,149** | **124** | **4,00E-09** | *** | **t-test** |
| | **sd(Y)** | **10,32** | **9,78** | | | | | |

The results of the two-sample t-tests for the type of secondary school as an independent variable X2 and the total creativity Y as a dependent (response) variable are presented in Table 2. It is shown that the achieved score of high school students in the TSD-Z test is significantly higher compared to vocational schools. The same trend applies to individual partial reviews. In most cases, the difference is statistically significant ($p < 0{,}005$). We also noted a positive correlation of $p < 0{,}05$ also in the categories of thinking fluency (Y4, Y5), overcoming borders (Y6, Y7), unconventional thinking, the courage to take risks in favor of gymnasium students. Therefore, we reject the null hypothesis and we confirmed the influence of the type of secondary school on the creativity of students determined by the TSD – Z test.

Verification of hypothesis H3

We verified hypothesis 3 using analysis of variance for $n = 126$, at the selected level of significance $\alpha = 0{,}05$. The results of the analysis of variance for the number of years of mathematics learning as an independent variable X3 and the total creativity Y as a dependent (response) variable are presented in Table 3.

**Table 3.** The results of the statistical tests for hypothesis H3

| | UrbT | 2 years | 3 years | 4 years | test statistic | df | p-value | sign | test |
|---|---|---|---|---|---|---|---|---|---|
| Y1 | Cn | 4,82 | 5,29 | 5,09 | 9,886 | 2 | 0,007 | ** | KW – test |
| Y2 | Cm | 4,63 | 5,26 | 5,09 | 14,42 | 2 | 0,0007 | *** | KW – test |
| Y3 | Ne | 3,39 | 3,47 | 3,09 | 0,744 | 2 | 0,69 | | KW – test |
| Y4 | Cl | 1,63 | 1,82 | 1,65 | 0,269 | 2 | 0,87 | | KW – test |
| Y5 | Cth | 2,2 | 2,17 | 2,48 | 0,496 | 2 | 0,78 | | KW – test |
| Y6 | Bfd | 1,71 | 2,29 | 2,09 | | | | | |
| Y7 | Bfi | 0,61 | 1,24 | 1,67 | | | | | |
| Y8 | Pe | 1,96 | 1,59 | 4,05 | 16,424 | 2 | 0,0002 | *** | chi-squared |
| Y9 | Hu | 3,31 | 4,59 | 4,19 | | | | | |
| Y10 | Uc (a) | 0,92 | 1,15 | 1,6 | | | | | |
| Y11 | Uc (b) | 1,78 | 1,41 | 2,23 | | | | | |
| Y12 | Uc (c) | 1,16 | 1,85 | 1,6 | | | | | |
| Y13 | Uc (d) | 2,08 | 2,74 | 2,23 | | | | | |
| Y14 | Sp | 0,49 | 0,18 | 0,63 | 3,806 | 2 | 0,15 | | KW – test |
| **Y** | **Sum** | **30,7** | **35,1** | **37,7** | **4,694** | **2; 123** | **0,01** | * | **ANOVA** |
| | **sd(Y)** | **9,32** | **10,53** | **13,24** | | | | | |

This table also presents the results of statistical calculations related to the verification of hypothesis 8. We performed hypothesis 8 for category Y1-Y14 using Kruskal-Wallis test, except for category Y8, where we used the chi-squared test. In this case, the minimum relationship $p = 0{,}010$, between the achieved creativity score and the number of years of math learning at secondary school is shown.

We used Tukey's honest significance test, or Tukey's HSD (honestly significant difference) test for the statistical significance of contrast. It can be used to find means that are significantly different from each other. The significant differences were confirmed only between students who studied mathematics for 2 years and 4.

Significant differences exist so for some partial scores. We were surprised by the outstanding results in the Y8 (perspective) and Y2 (completion) categories. The result obtained reflects the fact that the number of years of mathematics study does not provide relevant information on how much math the students actually learned. There are differences in the number of mathematics lessons at different types of high schools.

Verification of hypothesis H4

To verify hypothesis 4, we used Welch's *t*-test for unequal variances for the total creativity score Y, two sample Wilcoxon test for the sub-indicators and two proportion z-test. The results of this statistical tests for gender (independent variable X4) and total creativity Y as a dependent (response) variable are presented in Table 4.

**Table 4.** The results of the statistical tests for hypothesis H4

| | UrbT | M | F | test statistic | df | p-value | sign | test |
|---|---|---|---|---|---|---|---|---|
| Y1 | Cn | 5,03 | 5,05 | 2014 | | 0,87 | | Wilcoxon |
| Y2 | Cm | 4,97 | 4,95 | 2015,5 | | 0,87 | | Wilcoxon |
| Y3 | Ne | 3,2 | 3,41 | 1803 | | 0,37 | | Wilcoxon |
| Y4 | Cl | 1,77 | 1,61 | 2072 | | 0,65 | | Wilcoxon |
| Y5 | Cth | 2,42 | 2,16 | 2102,5 | | 0,55 | | Wilcoxon |
| Y6 | Bfd | 2,44 | 1,55 | 2,481 | 1 | 0,12 | | 2 prop z-test |
| Y7 | Bfi | 1,22 | 1,07 | 0,02 | 1 | 0,89 | | 2 prop z-test |
| Y8 | Pe | 2,81 | 2,32 | 0,556 | 1 | 0,46 | | 2 prop z-test |
| Y9 | Hu | 4,22 | 3,68 | 0,774 | 1 | 0,38 | | 2 prop z-test |
| Y10 | Uc (a) | 1,17 | 1,26 | 0,022 | 1 | 0,88 | | 2 prop z-test |
| Y11 | Uc (b) | 2,02 | 1,65 | 1,535 | 1 | 0,22 | | 2 prop z-test |
| Y12 | Uc (c) | 1,64 | 1,35 | 0,794 | 1 | 0,37 | | 2 prop z-test |
| Y13 | Uc (d) | 2,3 | 2,32 | 0 | 1 | 1 | | 2 prop z-test |
| Y14 | Sp | 0,45 | 0,45 | 1977,5 | | 0,99 | | Wilcoxon |
| **Y** | **Sum** | **35,7** | **32,8** | **1,139** | **122,98** | **0,17** | | **Welch t-test** |
| | **sd(Y)** | **13,5** | **18,25** | | | | | |

As expected, there is no relationship between the assessment of students' creativity by the Urban test and the gender of students. This applies both to the overall score and all sub-indicators. The results are not surprising, as similar results were recorded, for example, in the works of Szobiová (2002).

Verification of hypothesis H5

To verify hypothesis 5, we again used two-sample t-tests for the total creativity score and two sample Wilcoxon test for the sub-indicators and two proportion z-test for $n = 126$, at the selected significance level $\alpha = 0{,}05$. The results of the two-sample t-tests are presented in Table 5.

Once again, the dependence was relatively stable. However, this was particularly evident in the overall assessment, with partial results, only minor differences were presented. We can, therefore, confirm the positive impact of higher education of parents on the development of the creative competencies of the individual.

**Table 5.** The results of the statistical tests for hypothesis H5

| | UrbT | 2 | 3 | test statistic | df | p-value | sgn | test |
|---|---|---|---|---|---|---|---|---|
| Y1 | Cn | 4,99 | 5,11 | 1746,5 | | 0,26 | | Wilcoxon |
| Y2 | Cm | 4,9 | 5,04 | 1778,5 | | 0,35 | | Wilcoxon |
| Y3 | Ne | 3,21 | 3,44 | 1736,5 | | 0,28 | | Wilcoxon |
| Y4 | Cl | 1,3 | 2,2 | 1378 | | 0,003 | ** | Wilcoxon |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Y5 | Cth | 1,99 | 2,69 | 1607 | | 0,07 | | Wilcoxon |
| Y6 | Bfd | 1,77 | 2,29 | 0,682 | 1 | 0,41 | | 2 prop z-test |
| Y7 | Bfi | 0,76 | 1,64 | 3,388 | 1 | 0,07 | | 2 prop z-test |
| Y8 | Pe | 2,11 | 3,16 | 3,2 | 1 | 0,07 | | 2 prop z-test |
| Y9 | Hu | 3,38 | 4,69 | 5,642 | 1 | 0,02 | * | 2 prop z-test |
| Y10 | Uc (a) | 1,01 | 1,47 | 2,406 | 1 | 0,12 | | 2 prop z-test |
| Y11 | Uc (b) | 1,52 | 2,24 | 6,443 | 1 | 0,01 | * | 2 prop z-test |
| Y12 | Uc (c) | 1,22 | 1,85 | 4,646 | 1 | 0,03 | * | 2 prop z-test |
| Y13 | Uc (d) | 2,32 | 2,29 | 0 | 1 | 0,99 | | 2 prop z-test |
| Y14 | Sp | 0,42 | 0,49 | 1868,5 | | 0,55 | | Wilcoxon |
| **Y** | **Sum** | **30,92** | **38,6** | **-4,001** | **124** | **0,00006** | *** | **t-test** |
| | **sd(Y)** | **11,26** | **10,24** | | | | | |

**5. Discussion**

Several reasons led us to solve the research issue above. These were mainly the tendencies prevailing in the implementation of school reforms in Slovakia. They are trying to reduce the teaching of mathematics at all types of schools; the final exam leaving exam at secondary schools for more than 10 years has not been compulsory. Many students are coming to technical universities whose knowledge of secondary school level of mathematics is minimal. These students consequently have significant problems in mastering mathematical subjects as well as subjects closely related to it (physics, operational analysis, etc.). Of course, there are also students with excellent knowledge of mathematics (they are those who graduated from mathematics – in 2019, it was only 12 % of all secondary school students). We notice a significant knowledge gap between these groups.

Our belief that mathematics education should not be minimized, but rather expanded, is based on the fact that mathematical activities include analytical, synthetic, deductive, inductive, divergent thinking, which is potentiated in the process of mathematical education. The period we live in, in which routine and stereotypical activities (whether manual or mental) can be performed by technology for us, need to put the development of an individual's creative potential at the forefront of the educational process (that is the activities or things technology cannot do for us). We need people with clear, original, innovative and divergent thinking.

The research works of Sequera (2007) consider creativity as a methodological element that helps to acquire mathematical knowledge and ensures that general creative skills are also developed while solving mathematical problems. Several studies are describing the relationship between mathematical knowledge and the development of creativity. Authors such as Krutetskii (1969) and Ellertoh (1986) suggest the existence of an implicit relationship between problem-solving capabilities (level of creativity) and the mathematical competence of an individual. The existence of a relationship between creativity and problem solving is also mentioned by (Callejo, 2003), which emphasizes that if one is forced to solve problems, one's creativity is activated. Ayllón and Gómez (2014) argue that problem-solving mathematical problems activate students' creative thinking, and in turn, improve mathematical thinking.

Similarly, we believe that creative thinking and mathematical thinking are "connected bowls" that interact with each other. In our work, we, therefore, tried to point out the existence of a relationship between mathematics education and creativity.

Hypothesis 1 confirmed the strong relationship between the student's creativity and his grade in mathematics. The Tukey HSD test showed the existence of two separate groups – one consisting of students with a grade of 1 or 2, the other students with a grade of 3 or 4. We can, therefore, say that a grade in mathematics (which to some extent, reflects the student's relationship to this subject) and creative abilities students are closely related. We can assume that students, better rated in the subject of mathematics, have better developed logical, analytical and divergent thinking and thus more competences in the field of creative thinking.

The relationship between creativity and the type of secondary school in hypothesis 2 pointed to the fact that gymnasium students, who generally have more mathematics lessons, achieve a higher creative thinking score than secondary school students where there is less mathematics. It was also interesting to note that higher education of parents has a positive effect on the creative potential of their children.

As expected, there is no relationship between the assessment of students' creativity by the Urban test and the gender of students. This applies both to the overall score and all sub-indicators. The similar results were recorded, for example, in the works of Szobiová (2002), Sequera (2007), Žák (2004).

## 6. Conclusion

Creativity and mathematics are disciplines that usually do not appear together. Both concepts represent complex elements of process sharing, such as fluency (number of ideas), flexibility (range of ideas), novelty (unique idea) and elaboration (development of ideas). These factors contribute, among other things, to the students being competent in mathematics. Problem-solving, research can be perceived as a suitable evaluation tool that points to a person's creative level.

We are convinced that, as creative and divergent thinking is part of mathematical solving processes, the components of mathematical thinking are: (deduction, induction, synthesis, analogy). They are inherent to the development of the individual's creative potential. We appeal to this fact with our paper as well. Mathematical education cannot "harm" anyone; on the contrary, it contributes to the development of such much-needed competences of the individual.

The primary function of education is to contribute to the development and perfection of society as a whole. Education enables the development and progress of society. For the society in which we live, receiving, transmitting and application of new knowledge, which becomes its part, is typical. Education is related to the holder whose only task is a continual completion of his/her theoretical knowledge and practical skills for his/her personal as well as society-wide benefit (Plavčan, 2006). The educational policy acquires new dimensions that become an inseparable part of the present society (Chuguryan, 2008).

The aim of a knowledgeable society has to be a desire for wisdom, understanding the world, self-knowledge and self-formation, desire to observe the world mentally and to understand its laws, desire to create, construct and cultivate a practical wit. It has to respect a complex development of cognitive, psychomotor and socio-affective sides of a personality (Turek, 1998). Education becomes one of the most important factors influencing employment.

Creativity is an essential feature of a personality that is used in everyday life. It allows us to be flexible in dealing with many life situations. Mathematical education can also be seen as one of the opportunities for developing an individual's creativity. Therefore, in this paper, we also want to fight for this statement: give mathematics a chance, do not perceive it as an unpopular and useless subject. However, we need people for the future who are not afraid to think original, flexible, courageous and, above all, using their creativity. Solving of mathematical problems will lead to the development of creativity (Haylock, 1987). For that reason, it is important to develop mathematical strategies and instruments favoring the creative learning in our classrooms.

John Adam (2006) wrote: „There exist two types of education: One teaches us how to earn a living and the other one how to live".

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