Non-cognitive factors in the development of combinatorial thinking in future elementary school teachers

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Abstract. The article describes the study of the effectiveness of methodological techniques used in classes with students training to become teachers of mathematics in elementary schools in accordance with the methods of teaching mathematics to elementary school students. The methods proposed by the authors activate the mutual connection between logical thinking and several non-cognitive abilities of students. This reciprocal relationship is seen as a means to diagnose and develop students' combinatorial abilities. The study uses testing methods with subsequent mathematical processing. The non-cognitive factors (level of general cultural development, general humanitarian training, features of the micro-environment, as well as the level of general psychosocial development, etc.) are assessed through the methods of academic success diagnostics, expert assessment of the level of general cultural development, and assessment of the level of psychosocial development. The obtained data were compared with the level of development of students' logical thinking determined through the Raven test. The formative stage deployed original methodological methods allowing to stimulate students' interest in composing textual mathematical tasks. The proposed methodological solutions to the problems of diagnosing and developing combinatorial thinking understood as a combination of logical thinking and several non-cognitive factors in future teachers show themselves effective. The proposed hypothesis is that composing textual mathematical tasks for elementary school students is an effective means of developing combinatorial abilities in students. The main conditions stimulating the effectiveness of non-cognitive factors are the increase in the level of an individual's general cultural development, the expansion of their outlook, and the development of knowledge base, the creation of the "right" atmosphere for creativity, and stimulation of metaphorical thinking in the learning process.

Keywords: development of combinatorial thinking, non-cognitive factors, mathematics teaching methodology, compositions of mathematical problems, elementary school students.

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1 Relevance

The combination of cognitive and non-cognitive factors creates the basis for combinatorial thinking that presents a system of ways of allocating different options, permutations, combinations, and placements of elements in the relationships determined by the conditions of the task and its purpose. Considering the relevance of the problem of developing combinatorial thinking, researchers primarily draw attention to the close connection between the ability to solve problems using combinatorial abilities and academic and overall life success [1-6].

Modern teachers require combinatorial abilities to solve a variety of professional tasks of both theoretical and practical nature. Important evidence of the development of combinatorial abilities is the productivity of thinking in solving tasks of divergent type as it creates opportunities for achieving original results by analyzing, comparing, and combining a large number of options [7, 8] etc.

2 Theoretical background

Philosophical and psychological studies on the relationship between the cognitive and psychosocial spheres of personality have a long tradition in Russian science. In psychology, the problem of an inseparable connection between intellect and affect was first outlined by L.S. Vygotsky and developed by his students and followers (M.Iu. Basov, V.V. Davydov, V.P. Zinchenko, A.M. Matiushkin, V.V. Rubtsov, and others). Modern psychologists emphasize that properties of objects that are out of our field of vision and not consciously perceived, and are thus inaccessible to conscious control do not disappear without a trace but become the basis of intuitive experience that emerges regardless of an individual's desire and necessarily manifests later in thinking and behavior [9-11] etc.

The studies examining the factors determining a person's cognitive productivity in the process of problem-solving demonstrate apparent discrepancies among specialists. Some researchers argue that the main role is played by cognitive factors [12-14] etc. Other researchers believe that of primary importance are the non-cognitive factors [4, 8, 15-18] in which they include motivation, self-confidence, attribution style of successes and failures, etc.

Our study is based on the idea that for the development of combinatorial abilities in future teachers, of special importance is the combination of two characteristics: logical, consistent unidirectional thinking that develops in the process of education typically at the conscious level and serves as a basis for the acquisition of declarative knowledge and implicit knowledge hidden in the depths of the subconscious and acquired during general psychosocial development and students' mastery of various academic disciplines. Therefore, along with cognitive factors, it is expedient to consider non-cognitive factors including general humanitarian training, the breadth of interests, the level of knowledge in various areas, the degree of success in mastering subjects of general scientific, general vocational, and specialized training as the main factors in the development of students' combinatorial thinking.

3 Sample and methods

The sample of the study is formed by undergraduate students of the Moscow City Pedagogical University studying in the profile of "primary education" in direction of training "pedagogical education" and "psycho-pedagogical education".

The level of development of logical, sequential, unidirectional thinking abilities is assessed using J. Raven's test (computer version). The level of general intellectual development was evaluated by standard intelligence tests that allow obtaining quantitative coefficients of the subjects' intellectual development (H. Eysenck Intelligence Test).

Two groups of non-cognitive factors, namely general humanitarian training and the breadth of interests, were evaluated by experts in the course of conversations and observations. To increase the degree of objectivity of the expert assessment, the average indicator for each parameter was calculated for each student. The third group of parameters – "the degree of success in mastering academic subjects" – was determined by students' grades in educational programs.

4 Study design

Based on the theoretical provisions discussed above, we have adjusted the curricula for the modules "Methods of Teaching Mathematics in Elementary Schools" and "Professional and Personal Development of Future Teachers by Means of Information Technology". The structural elements of methodological support for the classroom and independent work of students, as well as technological maps of the studied disciplines ("Methodological foundations of teaching mathematics", "Methods of teaching problem-solving in elementary school"), were revised and clarified.

Along with classical methods for the development of teachers' methodological skills related to teaching mathematics to elementary school students, we used methodological tasks requiring independent thinking, originality, ingenuity, and a certain degree of novelty. As it turned out, the process of developing future teachers' combinatorial skills, the ability to solve problems in different ways, and creative thinking is much more complex than the process of mastering the basic content of the primary mathematics course and developing their theoretical style of thinking. This problem can be addressed by setting psychological and pedagogical and methodological tasks that require direct application of such a style of thinking.

The greatest effect is demonstrated by tasks associated with composing mathematical problems. Students constructed typical problem texts, texts of problems of increased complexity, and complex mathematical problems in the PISSA format and, at the same, time developed their combinatorial abilities at the expense of competencies in algebra, geometry, mathematical analysis, and mathematical statistics, as well as general humanitarian training and knowledge of the processes and phenomena of modern life.

A significant indicator of the combinatorial style of thinking is that the development of the text itself and the ways of solving the resulting problems is based on the multidimensionality and diversity of topics for the tasks on the one hand and the restrictions imposed by the content of the elementary mathematics course on the other. Therefore, this activity is directly linked to the manifestation of the combinatorial style of thinking implying that the search for solutions is not random and the "insights" are not solely based on intuition.

5 Discussion

The purpose of the empirical study was to test the correlation and mutual influence of combinatorial abilities and non-cognitive factors.

Correlation and analysis of variance were used to analyze the relationship and mutual influence between the scales (Table 1).

Table 1. Empirical values of correlation analysis.

	General humanitarian training	**Combinatorial abilities**	**Psychosocial development**	**Outlook**
Logical thinking abilities (IQ test, Raven, Amthauer)	0.842***	0.922***	0.839***	0.872***
General humanitarian training	—	0.704***	0.799***	0.823***
Breadth of interests	—	—	—	—
Success in mastering academic subjects	—	—	—	—
Combinatorial abilities	—	—	0.734***	0.769***

The analysis of the results allows us to formulate several conclusions reflecting the identified patterns. We have found that an increase in values of the "General humanitarian training" scale causes growth in the "Combinatorial abilities" scale. The obtained value $r=0.704$ ($p<0.001$) testifies to the presence of significant strong positive links between the "General humanitarian training" and "Combinatorial abilities" scales.

An increase in scores on the "Logical thinking abilities" scale also tends to be associated with a rise in the scores on the "Combinatorial abilities" scale. The correlation coefficient indicates a significant strong positive relationship between the "Combinatorial abilities" scale and the "Logical thinking abilities" factor ($r=0.922$; $p<0.001$).

Significant strong positive correlations ($r=0.734$; $p<0.001$) are observed between the "Combinatorial abilities" and "Psychosocial development" scales. Respondents who score higher on the "Psychosocial development" scale have higher indicators on the scale "Combinatorial abilities".

Significant strong positive correlations are found between the "Combinatorial abilities" scale and the "Outlook" scale ($r=0.769$; $p<0.001$). High scores on the "Outlook" scale correlate with similar scores on the "Combinatorial abilities" scale.

The conducted analysis of variance allows us to state that non-cognitive factors directly influence the process of development of combinatorial abilities in future teachers. The derived conclusion was tested using Levene's test and a statistically significant influence of the selected non-cognitive factors was discovered.

A single-factor analysis of variance was sufficient to test the impact of General humanitarian training on Combinatorial ability as no significant statistical differences were found between the variances ($F=2.957$; $p>0.05$). The General humanitarian training variable was found to have a statistically significant effect on the values of the Combinatorial ability scale ($F=32.294$; $p<0.001$). The highest value is observed at 5 points (7.1 ± 1.3), the lowest values at 2 points (44.6 ± 4.0).

Levene's test shows statistically significant differences between the distributions ($F=3.708$; $p<0,05$). This indicates that one-factor analysis of variance has to be carried out using Welch's correction. The analysis reveals a statistically significant effect of the "Outlook" variable on the values on the "Combinatorial abilities" scale ($F=7.126$; $p<0.001$). The highest value is observed at the high level (57.5 ± 0.5), the lowest values are found at the low level (46.5 ± 4.9).

Due to the absence of statistically significant differences between the variances according to Levene's test ($F=3.117$; $p>0.05$), the degree of influence of the level of development of logical reasoning abilities on combinatorial abilities was assessed through a single-factor analysis of variance. The detected influence of the variable "Theoretical foundations of the elementary course of mathematics" on the values on the "Combinatorial abilities" scale is

statistically significant (F=30.806; p<0.001). The highest value is observed at the level of 5 points (56.0±1.6) and the lowest is at the level of 3 points (46.5±4.9).

Finally, the overall level of students' intellectual development was assessed through two subscales of the G. Eisenk intelligence test characterizing general intelligence. We conclude that if future elementary school mathematics teachers have reserves of intellectual development, the intelligence coefficients characterizing it tend to rise.

6 Equations and mathematics

We understand the development of combinatorial thinking in future teachers as a combination of logical thinking and several non-cognitive factors – the coefficient of intellectual development, general humanitarian training, the breadth of interests, and the degree of success in mastering academic subjects. The proposed methodological solution to the problem of developing combinatorial abilities in students shows its effectiveness. The development of mathematical task compositions for elementary school students requires students to activate their cognitive abilities and psychosocial development levels and serves as an effective means of developing their combinatorial abilities.

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