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Formation of the Cognitive Component of Professionally-Oriented Mathematical Competence of Future Radio Specialists in the Context of Neuroplasticity of the Human Brain

Alona KOLOMIIETS[1],
Olha KRAIEVSKA[2],
Yaroslav KRUPSKYI[3],
Oksana TIYTIYNNYK[4],
Iryna KLIEOPA[5],
Ihor KALASHNIKOV[6]

[1] Vinnytsia National Technical University, Vinnytsia, Ukraine, alona.kolomiets.vnt@gmail.com

[2] Vasyl' Stus Donetsk National University, Vinnytsia, Ukraine, olha.kraievska@gmail.com

[3] Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Vinnytsia, Ukraine, kruyarik@gmail.com

[4] Vinnytsia National Technical University, Vinnytsia, Ukraine, tutunnik.oksana@gmail.com

[5] Vinnitsia National Technical University, Vinitsia, Ukraine, paceka08@gmail.com

[6] Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Vinnytsia, Ukraine, kalashnikov.igor.1@gmail.com

Abstract: *The article is devoted to the disclosure of the problem of formation of competencies of future specialists in technical specialties, in particular students of radio engineering specialties. The main concept for the formation of skills and abilities of students is the theory of neuroplasticity of the human brain, which is the basis of all neuropedagogy. The essence of the phenomenon of neuroplasticity of the brain is analyzed in the work, the analysis of works of scientists who investigated the problem of formation of competences of future specialists of technical specialties, in particular formation of mathematical competences is carried out.*

The concepts of competence and professionally-oriented mathematical competence are specified. The authors singled out in a separate block professionally-oriented mathematical competence as fundamental, which is an integrative formation of mathematical and professional skills. It includes the following components: cognitive, operational-algorithmic, applicable, design components. The cognitive component of professionally-oriented mathematical competence is responsible for the ability to find and accumulate mathematical knowledge. In order to improve the quality of training of future specialists in technical specialties, a methodical system of fundamentalization of mathematical training of future bachelors in the field of electronics and telecommunications has been formed.

Elements of test tasks are offered, by means of which the formation of the cognitive component of professionally-oriented mathematical competence was checked.

The article makes a detailed description of the statistical verification of the obtained experimental data and the results of the empirical verification of the effectiveness of the method. Mathematical processing of data and their reliability and significance were checked using Fisher's test. The results of the experiment gave grounds to assert that the effectiveness of the proposed methodological system does not depend on the individual personality of the lecturer who introduced the method into the educational process.

Keywords: *mathematical training; electronics and telecommunications; technical specialties; neuropedagogy; fundamentalization of mathematical training; future bachelors.*

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Introduction

The leading place in the training of the future technical specialist is occupied by the formation of a number of basic, key competencies that will reflect his ability to work in engineering. Prominent among them is mathematical competence, and ways of its formation, which is possible under the condition of introduction into the educational process of the competence approach, formation of conditions that promote it. Accordingly, the introduction of the competency approach and its main components in the educational process occupies a leading position in the educational process in higher technical educational institutions.

The basis of the formation of personality competencies is the basic principles of neuropedagogy, in particular, knowledge about the formation and development of the human brain, the laws of neuroplasticity of the brain.

The theory of neuroplasticity of the brain emerged relatively recently, in the second half of XX century. It is based on the hypothesis that the acquisition of knowledge occurs at the psycho-physiological level of man, the formation of human skills is a complex process, which at the neural level means neurons of the human brain.

The issues of formation of professional and basic competencies are devoted to the work of Gerasymova et al. (2019), Melnyk et al. (2019), Nerubasska & Maksymchuk (2020), Sheremet et al. (2019) approach to the educational process devoted to work, Ovcharuk O.V. (2009) and many other scientists. Scientists Rakova S.A. (2006), Alpera B. (2013) and others are devoted to the problem of formation of direct mathematical competence. At the same time, not enough attention is paid to the issue of formation of professionally-oriented mathematical competencies in the scientific works of researchers known to us.

Caroline Leaf (2015), Lara Boyd (2015) and others have devoted theories of brain neuroplasticity and the application of this phenomenon in the educational process. Modern research convinces scientists of the need to move pedagogy to a new deeper level - the level of neuropedagogy. The phenomenon of neuroplasticity of the human brain is a decisive factor in the theory of neuropedagogy.

Our brain is made up of neurons, between which impulses pass, the impulse that arises in the brain between neurons indicates that a certain action has taken place. The impulse passed by my neurons leaves an imperceptible trace at first, and later, with repeated action, the impulse passes in the same way, as if remembering the trajectory. The depth and

strength of the connections between the neurons through which the impulses pass reflects the acquired skills. The phenomenon of neuroplasticity of the human brain is that when a person repeats a certain action, neural connections resembling tree branches are formed in his brain. The formed competence resembles a tree with branches, the so-called neural tree, newer connections are superimposed on older connections between neurons, which correspond to actions that are not practiced.

Modern technologies of medical engineering have made it possible to carry out in-depth research in the field of skills at the level of neural connections of the human brain, and accordingly it has made it possible to trace the formation of individual competencies.

American researcher Professor Lara Boyd (2015) studied the changes in the brains of students after a certain system of actions and loads. Before and after the experiment, a group of students took brain scans using computed tomography. During the experiment (between tomographic examinations) students had to systematically perform these actions. The computer images showed the formation of subjects in those areas of the brain of the subjects who are responsible for certain activities. That is, the formed skill is displayed as a brain new growth (a branch of a neural tree).

The idea of neuroplasticity of the human brain is precisely the mechanism on the basis of which the formation of abilities and skills Caroline Leaf (2015), and the language of the competence approach: the formation of personality competence.

The branching of the tree of neural connections of the human brain indicates the formation of new abilities and skills, the development of connections between neurons is the result of a system of sequential human actions. The branching and strength of connections between neurons reflects the established system of knowledge and skills to apply this knowledge.

Neuroplasticity of the brain can be described as changes in synapses and nerve chains, which are formed in response to changes in human behavior, environment and nervous processes.

The connections between neurons are formed gradually. The new human action that it performs systematically promotes the systematic passage of the impulse between the neurons of the brain. Each such impulse leaves a thin mark after its passage. If the action is stopped, then, as scientists say, this trace will disappear over time, and if the action is repeated for a certain period of time, the pulse will pass between the neurons constantly and should take the form of a tree branch. Thus, new branches appear on the "trees" of neural connections. According to scientists, for the

appearance of a new branch on the "neural tree" (as scientists call it) you need to repeat the same action for 21 days, to fix it takes another 21 days, and another 21 days for the impulse connection between neurons to take root, so that the performed action, habit, skill passed into the subconscious.

At the same time, as proved by scientists in the field of brain neuroplasty, various parts of the brain that have been less active so far are beginning to work actively. And a new branch in the neural tree of the human brain is responsible for a certain skill that she has mastered.

It is the neuroplasticity of the brain that explains the formation of skills in students, which are formed as a result of the systematic repetition of certain actions. For future engineers, the ability to find, select and accumulate mathematical knowledge and apply it in solving professional problems and in solving professional problems is important and fundamental. The cognitive component of professionally-oriented mathematical competence of future specialists, which is formed in the process of fundamental mathematical training, is responsible for the selection and accumulation of mathematical information. Therefore, the subject of research is the formation of professionally-oriented mathematical competence of future bachelors of technical specialties.

DeSeCo experts define the concept of competence as *the ability to successfully meet individual and social needs, act and perform tasks*. It is noted that the structure of competence includes knowledge, cognitive and practical skills, attitudes, emotions, values and ethical norms, motivation Ovcharuk, O. V. (2003).

The formation of the future specialist in technical specialties as an engineer is based on the acquisition of mathematical knowledge and the formation of mathematical skills and abilities, i.e. on mathematical competencies Petruk V.A. (2006). Therefore, the key factor is the selection of basic mathematical competencies that directly affect the general professional training of the engineer.

Competency is defined by the vast majority of researchers as knowledge, personal experience and the range of issues in which a person is competent. Some researchers use the terms "competency" and "competence" synonymously, but most tend to think of different meanings of these concepts. As noted by Golovan M.S., the concept of "competence" is associated with the sphere of human activity, and the concept of "competence" is associated with the individual and characterizes his ability to perform activities.

Competency "directly" is related to competence, how specifically it defines the predetermined range of issues and in the field of activity with

which a person should be well aware, competent. In other words, competence is a certain, predetermined, set of knowledge, skills, abilities, competence - a qualitative characteristic of their assimilation, which is manifested in the process of practical activities Leiko S.V. (2013).

We will define competence as the ability of a person to successfully perform the tasks set before him, on the basis of his own knowledge and skills, a set of professional knowledge and skills, to successfully navigate in the problematic issues.

In his work, B. Alpers (2013) highlights the main mathematical competencies of future engineers: *mathematical thinking, mathematical reasoning, formulation and solution of mathematical problems, mathematical modeling* (the ability to analyze and work with existing models and the ability to perform active modeling), *processing of mathematical symbols, mathematical communication, the creation of aids and tools*.

Professionally-oriented mathematical competence is essentially mathematical competence, and on the other hand it includes elements of professional orientation. *Vocational-oriented mathematical competence (VOMS) is a set of mathematical and professional competencies integrated into a single structural unit, which is a measure, a criterion of quality general scientific, professional training of future specialists and is formed in the conditions of fundamental mathematical training of future bachelors*.

VOMS includes cognitive, operational-algorithmic, applicable, design components.

The cognitive component of professionally-oriented mathematical competence reflects the formed system of knowledge of the student of the basic theoretical material, ability to accumulate mathematical knowledge, understanding of mathematical symbols, ability of the student to apply mathematical symbols in applied problems. The formation of the cognitive component of the VOMS of future bachelors in the field of electronics and telecommunications takes place in the process of introduction into the educational process of the methodical system of fundamentalization of mathematical training.

Under the fundamentalization of mathematical training of future specialists in technical specialties we understand improving the quality of the educational process due to the principle of knowledge, integrative approach, personality-oriented approach, which are the basis of the methodological system of fundamentalization of mathematical training of future technical specialists.

The aim of the work is to describe the experimental verification of the method of formation of competencies of future specialists, in particular,

the formation of the cognitive component of professionally-oriented mathematical competence of future specialists in technical specialties in the context of human brain neuroplasticity. The formation of this component will reflect the ability of future professionals to accumulate mathematical knowledge.

Materials & methods

Here is a description of the methodological system of fundamentalization of mathematical training of future bachelors in the field of electronics and telecommunications in general (because it is not the subject of this study).

The methodical system of fundamentalization of mathematical training of future bachelors consists of the following basic structural elements (Figure 1): goals, methods, tools, forms of education.

✓ *The aims* of the methodological system of fundamentalization of mathematical training of future bachelors in the field of electronics and telecommunications include:

✓ Fundamental mathematical training (MT) as part of the fundamentalization of the educational process as a whole (FET);

✓ The system of components of professionally-oriented mathematical competence (VOMS) is formed;

Qualitatively new level of teaching mathematical disciplines.

To test the formation of the cognitive component of professionally-oriented mathematical competence, we chose an experimental and control group of students in the field of electronics and telecommunications, on the basis of which an experimental test of the effectiveness of the proposed method of fundamentalization of mathematical training. The difference in the experiment in these groups was that in the experimental group the methodical system was introduced by the author of the method, and in the control group the methodical system was introduced into the educational process by another teacher who was provided with all necessary teaching materials. The peculiarity of the experiment, which distinguishes it from other experiments, is the verification of the effectiveness of the method in terms of its conduct by different lecturers.

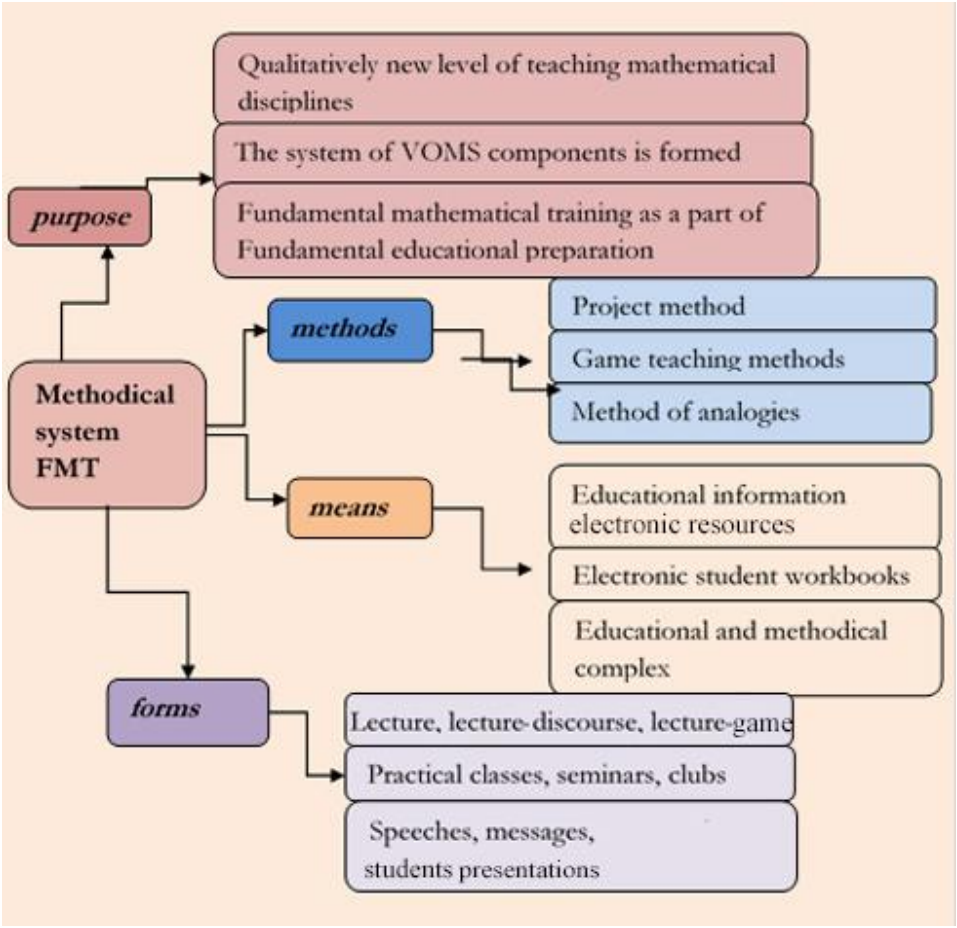

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Figure 1. *Scheme of the methodical system of fundamentalization of mathematical training (FMT) of future bachelors in the field of electronics and telecommunications*

The formation of competence can be checked and statistically assessed by assigning certain numerical characteristics (parameters) to the results of actions, changing these characteristics, their difference in the control and experimental groups of students after the experiment will indicate the effectiveness (ineffectiveness) of the proposed method.

Current control was proposed in both groups. Here is a partial list of tasks used to determine the level of formation of the cognitive component of professionally-oriented mathematical competence.

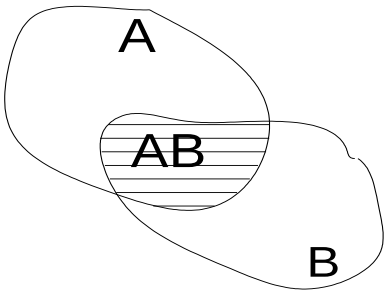
Sample test task
(to check the formation of the cognitive component of VOMS)

1. Choose the correct statement that matches the note:

$$A \cup B = C$$

1) A belongs to B**2.**
2) A at the intersection with B forms C
3) A in combination with B forms C
4) A and B are identical to C.

2. Choose the equation that describes the figure



$A \cup B = C$ $A \cap B = C$ $A \subset B = C$ $A \subset B = C$

1) 2) 3) 4)

3. Matrices A and B can be added if they are: a) consistent, b) conjugate, c) of the same dimension, d) similar

4. Matrices A and B can be multiplied if they are: a) consistent, b) conjugate, c) of the same dimension, d) similar

5. Write the definition of the determinant of the 2nd order.

6. For the function $z = x\cos y^2$ derivative $z'_x =$

7. А) $z'_x = \cos y^2$, б) $z'_x = 2\cos y^2$ в) $z'_x = 2x\cos y^2$ г) $z'_x = 2x$

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Students were tested by checking the formation of professionally-oriented mathematical competence and its components.

The purpose of the experiment at this stage was to ensure the effectiveness of the method, regardless of the teacher who introduces it into the learning process. For the reliability of the experiment it was necessary that 1) both lecturers conducted lectures and practical classes on the same and the same curriculum, 2) the basic elements of methodology were introduced into the educational process; 3) in both groups students performed levels of volume and difficulty of homework, 4) the level of requirements during the final control was the same, which was ensured by the presence of both lecturers in the exams in both groups of students.

Results

We first show that the groups of students selected for experimental testing are equivalent. Let's check the equivalence of the selected groups for *the quality of the exam.*

Let's make a table of comparison of experimental and control groups on the share of students, whose answers are referred to high, sufficient and medium, low levels according to the results of the first exam in the discipline of Higher Mathematics among students of EG and CG, Future bachelors in electronics and telecommunications (Table 1). The high level includes the answers of students who received the grade "excellent", the sufficient level includes the answers of students who received "good", the middle and low levels include the answers of students with grades "satisfactory" and "unsatisfactory".

According to the tables "The value of the angle φ for different percentages" (Sidorenko, 2002, p. 331) we find the values of φ, which correspond to the percentages of the "effect" in each of the groups: φ_1 (20%) = 0,927; φ_2 (26%) = 1,070.

Table 1. Comparison of the control and experimental group by the share of students whose answers are classified as high or sufficient and medium or low levels according to the results of the first exam in the discipline of Higher Mathematics

Group	"There is an effect"	"No ffect"	Total
Experimental	15(20%)	58(80%)	73(100%)
Control	28(25%)	82(75%)	110(100%)
Total	43	51	183

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The empirical value of φ * is calculated by the formula:

$$\varphi* = (\varphi_1 - \varphi_2) \cdot \sqrt{\frac{n_e \cdot n_k}{n_e + n_k}}, \quad (1)$$

where φ_1 – an angle corresponding to a higher percentage;

φ_2 - an angle corresponding to a smaller percentage;

n_e - the number of students in the experimental sample;

n_k - the number of students in the control sample.

$$\phi^*_{емп.} = (1,070 - 0,952) \cdot \sqrt{\frac{73 \cdot 110}{73 + 110}} \approx 0,143 \cdot 6,6341 \approx 0,9472$$

We obtained that $\varphi^*_{кр.} > \varphi^*_{емпір.}$, and therefore the obtained value $\varphi^*_{емп}$ = 0,9472 is in the zone of insignificance (Fig. 2)

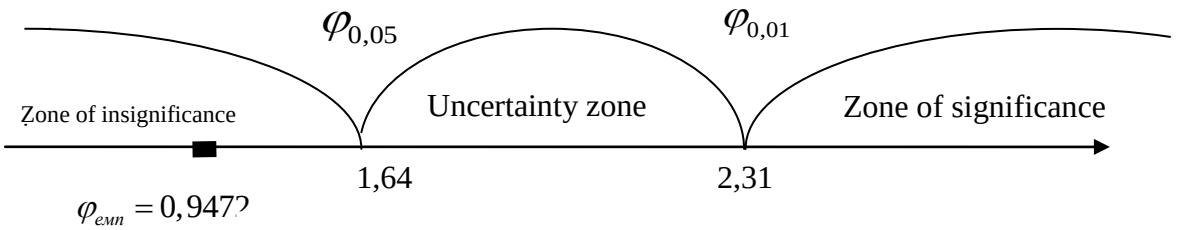

Fig. 2. Geometric interpretation of values критерію φ*

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Thus, the H1 hypothesis is refuted, and the H0 hypothesis is accepted that the initial levels of knowledge of students of the control and experimental groups are the same. Therefore, the selected experimental and control groups of students on *the criterion of quality of knowledge* can be considered as equivalent.

Then build a similar table with the results of the second final control.

Table 2. Comparison of the control and experimental group by the share of students whose answers are classified as high or sufficient and medium or low levels according to the results of the second exam in the discipline of Higher Mathematics

Group	"There is an effect"	"No effect"	Total
Experimental	18(27%)	48(73%)	66(100%)
Control	22(20%)	88(80%)	110(100%)
Total	132	51	183

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Based on the results of the obtained data, we construct a histogram for better perception of the data and their visual image (Fig. 3).

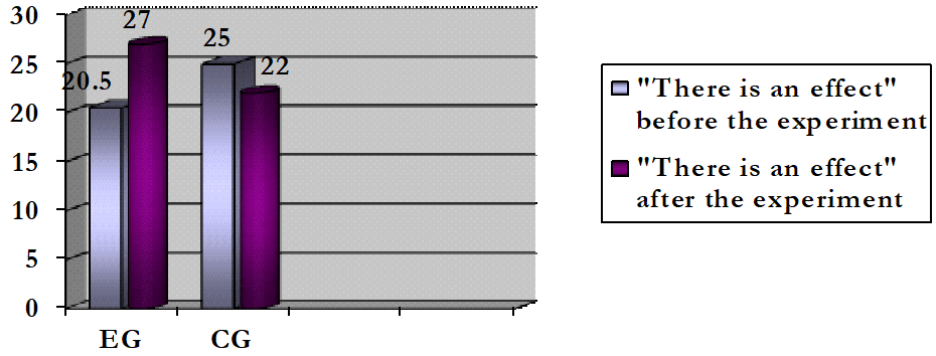

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Figure 3. Comparison of the shares of control and experimental groups in the presence of differences in the quality of education according to the results of the first and second final control

It is obvious that in the experimental group there is a tendency to increase the indicators of the category "there is an effect", where there was an increase of 6.5%, while in the control group in this category there was a decrease of 5%.

In order to conclude that the results of the implementation of the methodological system differ in the control and experimental groups due to the fact that the methodology was implemented by different lecturers, we will perform a statistical evaluation of the results using Fisher's test. And suppose that the differences are statistically significant. We write down the values for the particles in the control and experimental groups.

$\varphi_1(27\%) = 1{,}093$, $\varphi_2(20\%) = 0{,}927$

Applying formula (1) we obtain.

$$\phi^*_{емп.} = (1{,}09 - 0{,}927) \cdot \sqrt{\frac{66 \cdot 110}{66 + 110}} \approx 0{,}163 \cdot \sqrt{41{,}25} \approx 1{,}04$$

The obtained value is not statistically significant, and therefore we can conclude that the introduction of the methodological system by different teachers gives the same positive results.

Discussion

The study analyzes the effectiveness of the methodological system of fundamentalization of mathematical training of future specialists in the field of electronics and telecommunications. Research on testing the methodological system of fundamentalization of certain parts of the educational process has been described in the works of a large number of scientists, while the description of testing the effectiveness of fundamental methods of mathematical training of bachelors in electronics and telecommunications is not found in any known work. In addition, the leading idea of the study is to test the effectiveness of the method as a universal tool for forming the cognitive component of professionally-oriented mathematical competence of future bachelors, which does not depend on the personality of the lecturer who uses it. The conceptual position on which the formation of personality competencies is based is the neuroplasticity of the human brain. This concept is based on the hypothesis of the formation of skills and abilities of the individual.

Conclusions

The conducted theoretical and empirical research allows to draw the following conclusions.

1) The methodical system of fundamentalization of mathematical training of future bachelors in the field of electronics and telecommunications is an effective tool for improving the quality of education.

2) The result of the introduction of the methodical system of fundamentalization of mathematical training of future bachelors of radio engineering is the formation of professionally-oriented mathematical competence, and in particular its cognitive component.

3) The formation of the cognitive component was verified empirically by testing. The validity of the obtained results was checked using Fisher's angular criterion.

4) An important feature of the method of forming the cognitive component of professionally-oriented mathematical competence is the presence of a methodical system of fundamentalization of mathematical training of future bachelors in the field of electronics and telecommunications. In particular, the main components of the methodological system include goals, methods, forms, means of formation of professionally-oriented mathematical competencies of future professionals.

5) The leading achievements of neuropedagogy are taking into account the neuroplasticity of the human brain, taking into account the peculiarities of development and formation of the brain under the influence of external factors. The formation of skills and abilities is reflected on MRI images in the form of formations, which have been tested by foreign researchers.

6) It is concluded that the introduced method of fundamentalization of mathematical training of future bachelors in the field of electronics and telecommunications works regardless of the individual characteristics of the lecturer.

References

Alpers, B. A. (2013). *Framework for Mathematics Curricula in Engineering Education. A Report of the Mathematics Working Group.* European Society for Engineering Education, Brussels.

Boyd, L. (2015). Plasticity and the Brains of children with learning disabilities. http://www.neuroplasticityandeducation.com/wp-content/uploads/2015/10/lara-boyd.pdf

Gerasymova, I., Maksymchuk, B., Bilozerova, M., Chernetska, Yu., Matviichuk, T., Solovyov, V., & Maksymchuk, I. (2019). Forming professional mobility in future agricultural specialists: the sociohistorical context. *Revista Romaneasca pentru Educatie Multidimensionala, 11*(4 Suppl. 1), 345-361. https://doi.org/10.18662/rrem/195

Leaf, C. (2015). *Vklyuchite svoy mozg* [Turn on your brain]. Bright Books.

Leyko, S. V. (2013). *Ponyattya "kompetentsiya" ta "kompetentnist'" teoretychnyy analiz* [The concept of "competency" and "competence" theoretical analysis]. Pedagogy.

Melnyk, N., Bidyuk, N., Kalenskyi, A., Maksymchuk. B., Bakhmat, N., Matviienko, O., Matviichuk, T., Solovyov, V., Golub, N., & Maksymchuk, I. (2019).

Models and organizational characteristics of preschool teachers' professional training in some EU countries and Ukraine. *Zbornik Instituta za pedagoska istrazivanja*, *51*(1), 46–93. https://ipisr.org.rs/images/pdf/zbornik-51/Natalija-Meljnik.pdf

Nerubasska, A., & Maksymchuk, B. (2020). The Demarkation of Creativity, Talent and Genius in Humans: a Systemic Aspect. *Postmodern Openings, 11*(2), 240-255. https://doi.org/10.18662/po/11.2/172

Ovcharuk, O. V. (2003). *Kompetentnosti yak klyuch do formuvannya zmistu osvity // Stratehiya reformuvannya osvity Ukrayiny* [Competences as a key to the formation of the content of education // Strategy of education reform in Ukraine]. K.I.C.

Petruk, V. A. (2006). *Teoretyko-metodychni zasady formuvannya profesiynoyi kompetentnosti maybutnikh fakhivtsiv tekhnichnykh spetsial'nostey u protsesi vyvchennya fundamental'nykh dystsyplin* [Theoretical and methodological foundations of the formation of the professional competence of future specialists in technical specialties in the process of studying fundamental disciplines]. Universum-Vinnitsa.

Sheremet, M., Leniv, Z., Loboda, V., & Maksymchuk, B. (2019). The development level of smart information criterion for specialists' readiness for inclusion implementation in education. *Information Technologies and Learning Tools*, *72*, 273-285. https://journal.iitta.gov.ua/index.php/itlt/article/view/2561

Sidorenko, E. V. (2002). *Metody matematicheskoy obrabotki v psikhologi* [Methods of mathematical processing in psychology]. OOO "Rech".