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Educational Computer Programs Can be Used as a Tool to Help Students Develop Key Concepts and Cognitive Skills When Studying Mathematics

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Abstract: The article highlights the issue of improving cognitive processes in terms of individualization and personalization of learning paths, addressing the gap in students' basic mathematical knowledge through the use of digital technologies and computer-assisted learning systems. The presented computer-based mathematics training program with animated elements aims to ensure that students thoroughly comprehend key mathematical concepts, which are essential during the initial stage of university studies. To evaluate the effectiveness of implementing this program in the learning process, criteria were developed to assess students' mastery of educational material, the quality of their understanding of mathematical concepts, and the development of cognitive skills.The test revealed statistically significant trends in all the indicators studied (the degree of comprehension of the volume of concepts, the completeness of the development of the ability to work with concepts in problem-solving, the depth of understanding of the connections and relationships between a particular concept and others, as well as the mechanisms of memorization, comprehension, synthesis, analysis, and evaluation).

Keywords: *computer training program, mathematics: basic concepts of sequence limit and functions.*

1. Introduction

The issue of the competitiveness of university graduates in the field of pedagogical science is a long-standing one, and it is of significant importance, as it is reflected in research conducted in the fields of philosophy, economics, psychology, and pedagogy [1; 2]. Scientific and methodological studies demonstrate that education today is no longer feasible without the incorporation of digitalization. The Minister of Higher Education and Science of the Russian Federation, V.N. Falkov, has noted that even the traditional full-time learning format is undergoing transformation, with some elements of remote interaction between students and teachers becoming an integral part of it [3]. In this regard, the rector of the Higher School of Economics, N.Yu. Anisimov, has stated that «digitization is no longer a future possibility, but an unavoidable reality, and there is no alternative path for universities other than to adapt and achieve digital maturity».

It should be noted that traditional learning approaches cannot be discarded due to their merits. This is not the sole view in Russia, as J. Rohall, president of the European School of Management and Technology (ESMT Berlin), has stated: "Education is not merely a transfer of information, but a discussion, a debate on various concepts..." Similarly, Wei Shu, vice-president of the Hong Kong University of Science and Technology, has stated that "the educational process can only be effective with feedback from all parties involved." [4].

As practice has shown, the training of first-year students can be successful if:

- There is a solid foundation of high-quality pre-university training.
- Effective forms and methods of instruction are employed.
- Educational motivation and interest are present.

The first point, as a general rule, is crucial – with a poor level of school knowledge (in this case, mathematical knowledge), the motivation component quickly diminishes, which hinders first-year students' smooth and active entry into the learning process. For regional universities, this is a current reality, as the best graduates from schools with high Unified State Examination (USE) scores tend to enroll in capital-based educational institutions. A survey of schoolchildren revealed that the situation is not ideal. In St. Petersburg, out of 46 schools across 12 districts, only 5.9% of respondents answered "The school of the future" when asked "What does the school of the future mean to you?", and the answer "A foundation for education" was selected by [5] respondents. Many higher education mathematics teachers note the poor quality of school mathematics knowledge [6].

Obviously, such a scenario at the start of the first term, when the fundamental principles of higher mathematics are introduced through the study of disciplines such as "Algebra", "Analytical Geometry" and "Mathematical Analysis", would not allow weaker students to develop appropriate academic skills, and subsequently, to correctly master more complex subjects and engage successfully in research activities. By "correct perception", we mean the perception cycle of the "Y" model, as proposed by Neisser [7]. This model reflects such characteristics of perception as objectivity, structure, selectivity and meaningfulness.

Today, a variety of innovative tools, including computer-based solutions, are utilized to address this challenge. Computer software for training initially emerged in the United States in the 1940s (flight simulators). Due to the high cost of computers at the time, their size, the limitations of monitors, and the need to input programs using first-generation programming languages via punch cards, as well as limited access to computers only in specialized centers, the widespread adoption of computers in scientific, technological, and educational settings was hindered.

In the 1960s and 1970s, the primary programming language paradigms were developed, which continue to be used today. During the 1980s, consolidation occurred, with some languages adopting object-oriented features and system programming concepts, while others focused on the potential of modules.

After 1980, the availability of personal computers led to the emergence of leading companies in the field, primarily from the United States, that specialized in educational software. The primary goal of this software was to enhance the efficiency of educational processes.

In 2020, at the third international conference, eSTARS 2020, which focused on the study of the role of digitalization in higher education, Rector of the Higher School of Economics, Ya. Kuzminov, noted that in many universities in the country, there is a lack of implementation of digital technologies due to insufficient professional training of teachers and a well-established perception that digital education (particularly online) is of low quality. It is evident that the introduction of digital elements into the educational process in higher education should be based on a variety of high-quality content.

Today, many countries around the world are actively seeking new pedagogical approaches and techniques that, combined with digital technologies, can ensure universal learning, including by activating the learning process, individualizing it, and providing access to modern resources from leading experts in various fields.

The authors of a joint study conducted by the British Organization for the Development of Digital Technologies in Higher Education (Jisc) and the Emerge Education Investment Fund believe that it is time for a complete transformation of teaching in universities.

In their research, titled "Roadmap to 2030" [9], the authors identify three areas in which digital technologies can be most beneficial: educational content (improving the quality of digital curriculum), its delivery through learning and assessment infrastructure, and support for the educational process.

According to the results of a survey of 74 British educational institutions, it has been found that information technologies are most commonly used for convenience rather than for improving teaching effectiveness [10].

In Germany, research has been conducted to assess the level of proficiency of university teachers and students in using digital media. The findings indicate that both groups are underprepared for working in a collaborative digital environment [11]. Similar results have been observed in other countries such as Australia, Spain, New Zealand and the United States [12; 13].

American scientists, led by R.E. Mayer [14], have identified great potential for multimedia learning. They have defined multimedia learning and developed principles such as coherence, signaling, redundancy, spatial and temporal proximity, segmentation, modality, and others.

In addition, the experience of using multimedia technology is valuable, especially in a pandemic, and it should be further developed and expanded. This is relevant in improving the educational process [15]. Many Russian scholars see the use of multimedia technology as a new and more progressive approach to teaching [16;

17; 18]. The article [19] emphasizes the importance of incorporating digital technologies and systems into education, as they make the learning experience more effective and engaging.

Computer training programs (CTPs) that are skillfully written with built-in animations, as mentioned previously, make the learning process more visual, appealing, and engaging. The effectiveness of this approach is demonstrated in the works cited [20-27]. While there are some effective CTPs in higher mathematics, it should be noted that their number is relatively small. This is because professional programmers often lack knowledge of appropriate methodologies, while mathematics teachers, for the most part, do not possess programming skills.

The purpose of the study: optimization of the educational process through the use of a computer training program with animation elements in the formation of basic knowledge and cognitive skills of bachelors.

The object of the study: First-year students from the fields of applied mathematics, computer science, and computer engineering, as well as information security, from the Institutes of Mathematics, Natural Sciences and Technology, Economics, and Management, are invited to participate in the event.

The selection of the first courses is based, as previously noted, on a poor knowledge of basic mathematics and the need to rapidly engage former applicants in the field of higher mathematics through interest, which evolves into a motivational trend with a dynamic nature that contributes to the development of scientific interest.

2. Research methods and materials

One of the methods for enhancing the cognitive activity of university students is the incorporation of computer technology into the educational process, particularly in relation to the organization of independent study [28, 29, 30, 31]. This article discusses a computer-based training program with animated elements developed at I.A. Bunin State University (YSU). The program aims to supplement the fundamental mathematical knowledge acquired in secondary school, which is essential during the initial stages of university study.

Cognitive mechanisms in the form of vivid and dynamic images capture attention, stimulate thought, activate students' cognitive abilities, and aid in better retention of material. At these points, the emotional state can be described as a complex and multifaceted process involving several components, including cognitive, motivational, and motor aspects [32].

During the first week of the academic year at the Institute of Mathematics, Natural Sciences, and Technology of YSU named after I.A. Bunin, over the past three years (2020-2023), applicants were assessed on their knowledge of the fundamentals of elementary mathematics, including modules, sets, limitations, elementary functions, and trigonometry. Only 20% of high school graduates and 9% of graduates from secondary vocational programs were able to correctly answer 50% or more of the questions. This situation prompted me to develop a computer program that offers learning functionality and helps students quickly fill in any knowledge gaps during this critical period of their studies. The program is designed to be used in conjunction with traditional classroom instruction and

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provides additional resources and practice opportunities for students to improve their understanding of the material.

The training program is a set of six software modules: "Limit of sequence", "Function of one real variable", "Limit of function", "Continuity of function", "Derivative", "Applications of derivative", focusing the attention of first-year students on such important concepts of mathematics as modulus of number, limit of sequence, limit and continuity of function, points of discontinuity of functions, plotting of functions. As an example, consider the "Sequence Limit" module.

The motivation for addressing this topic was the analysis of the test results. It turned out that there is a large–scale misunderstanding of the expression "$|x - 2| < 3$", which in a slightly modified form will be used later in the topics "Sequence limit", "Function limit". Obviously, this misunderstanding is a direct consequence of the inability to work with an absolute value or a module.

The "Sequence Limit" program module is presented in three sections: Module, Association, and Limit. When the "Module" button is selected, the program shows students the formula for the numerical module in the school context, demonstrates and explains the concept error that this formula "presents" to students (Figure 1), and proposes applying another, more "general" formula (Figure 2), based on extensive teaching experience during the first years.

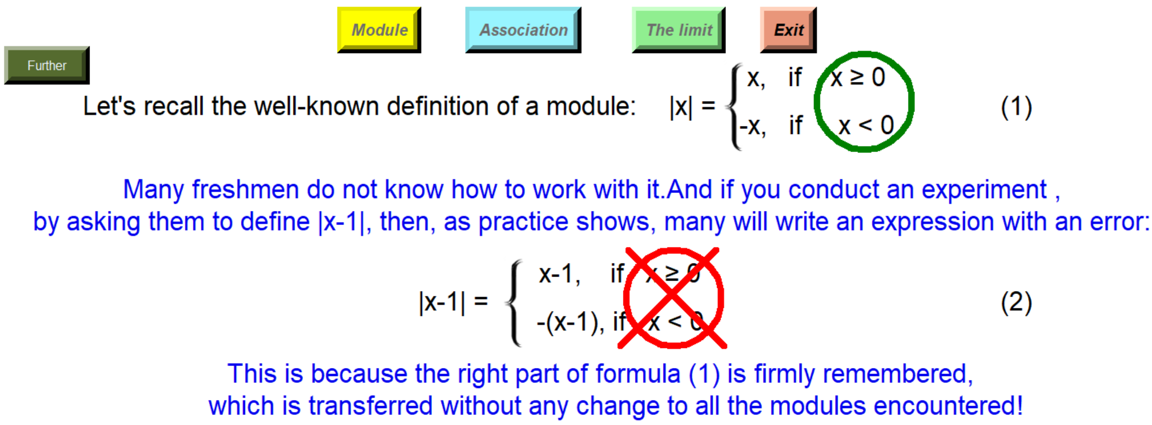

Figure 1 - A typical mistake of first-year students when working with the module

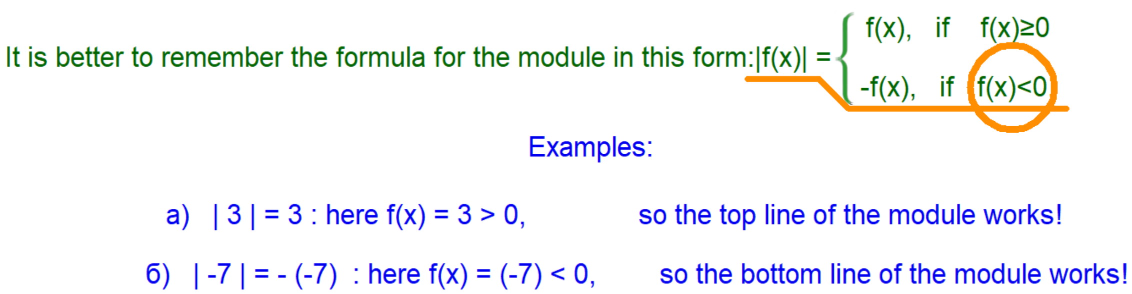

Figure 2 - The universal formula for the module

Later, various examples of the difference between two numbers on the numerical axis encourage students to draw the correct conclusion (Figure 3).

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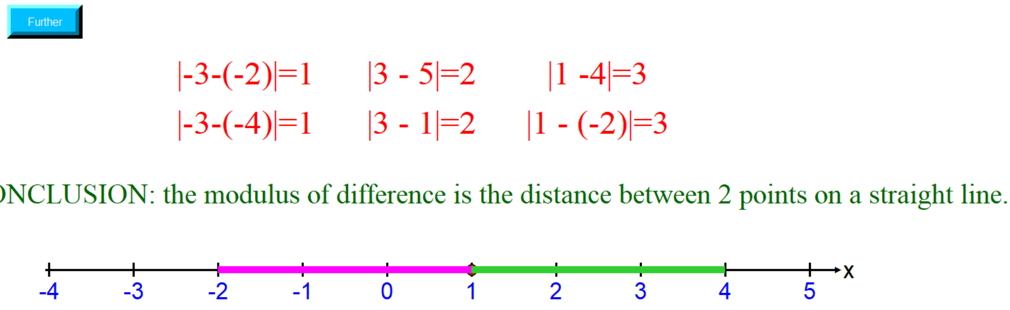

Figure 3 - Formation of the concept of the modulus of the difference between two numbers

After discussing the inequality |x - 3| < 2 on the number line (Figure 4), the geometric interpretation of the definition$|x - a| < \varepsilon$ becomes clear (Figure 5).

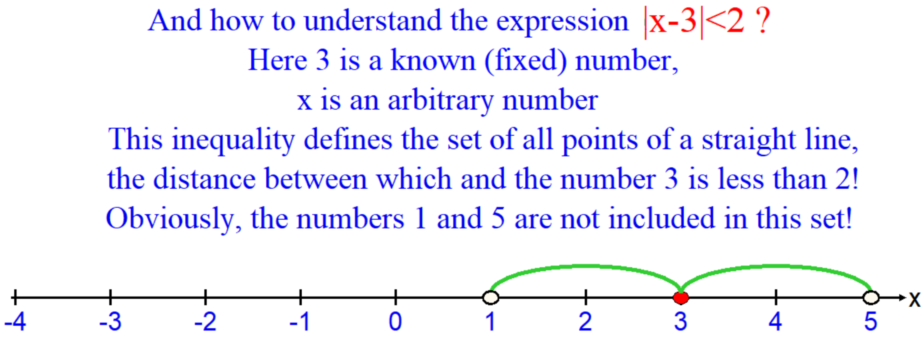

Figure 4 - Discussion of inequality $|x - 3| < 2$

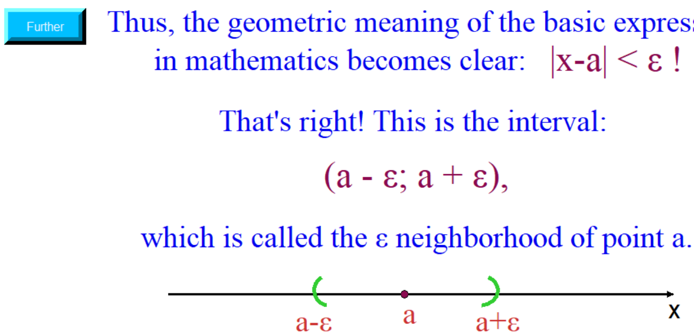

Figure 5 - The key inequality of mathematical analysis

Next, a transition is made to the "Association" section (menu button), where Zenon's famous paradox "Achilles and the Tortoise" is presented in animated form, which "demonstrates" that Achilles will never overtake the tortoise (Figures 6 and 7).

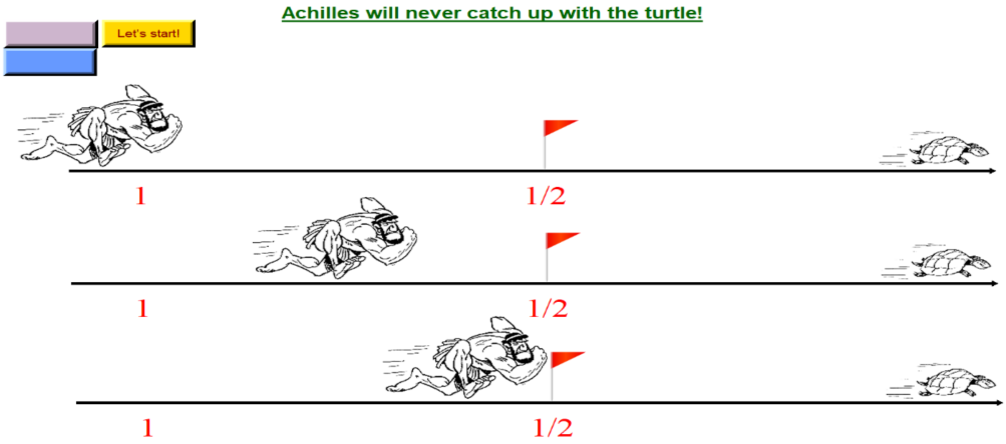

Figure 6 - The animation of Achilles

Part of the program code is presented below:

```
def clicked1():
    global k, k1, q4
    ac_kn(0, knop1)
    ac_kn(0, knop4)
    for i in range(1,250):
        cnv.move(id_img1, 2, 0)
        cnv.update()
        sleep(0.01)
    knop1.configure(text="CONTINUE!")
    if q4 < 4:
        t_ext(-20,-270+40*q4, spisok[q4], zw="DarkGreen", grup="group5", ti=mF2)
    q4 = q4 + 1
    ac_kn(1, knop2)
def clicked2():
    global k, k1, tex_1, tex_2
    ac_kn(0, knop2)
    ac_kn(0, knop4)
    cnv.delete(tex_1)
    cnv.delete(tex_2)
    for i in range(1,250):
        cnv.move(id_img1, -2, 0)
        cnv.update()
    tex_1 = cnv.create_text(-540, 254, text=Fraction(k1/2), fill="red",
```

```
                  font=('Times', 35))   # The beginning of the path
tex_2 = cnv.create_text(22, 254, text=Fraction(k1/4), fill="red",
                  font=('Times', 35))   # The middle of the road
k1=k1/2
k=k+1
ac_kn(1, knop1)
if k >= 5:
    ac_kn(1, knop4)
```

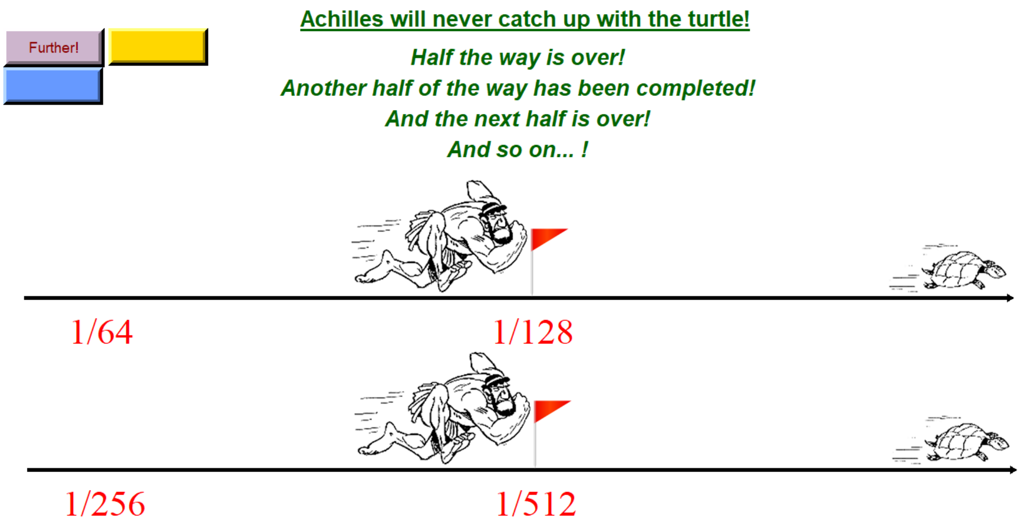

Figure 7 - The infinity of the process (the results are shown in a step)

In this context, students learn about the concept of the sequence limit. Achilles can get as close to the turtle as he wishes, but he will never be able to touch it (see Figure 8).

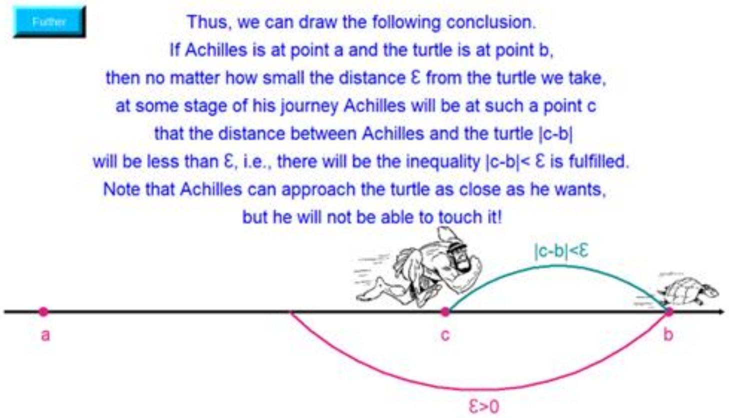

Figure 8 - The essence of the sequence limit

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In the "Limit" section, after defining the sequence, examples of various types of limits are provided (see Figure 9).

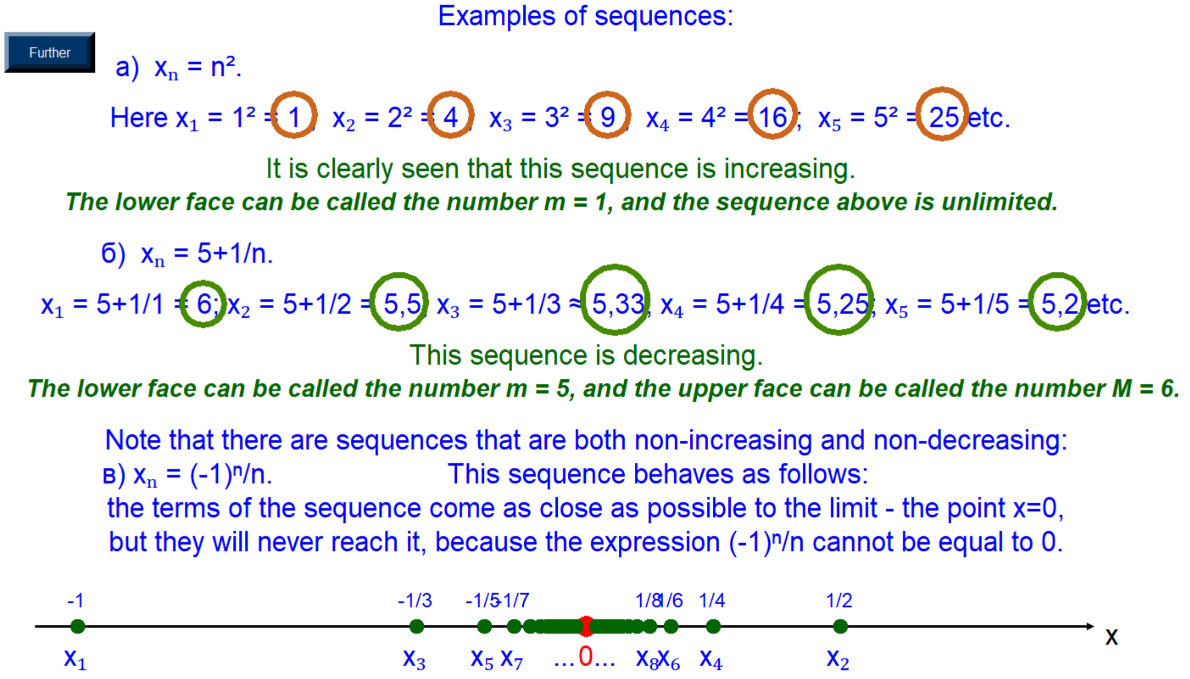

Figure 9 - Different kinds of sequences

Further, considering the increasing sequence on a straight line, the dependence is shown in dynamics N(ε) (see Figure. 10).

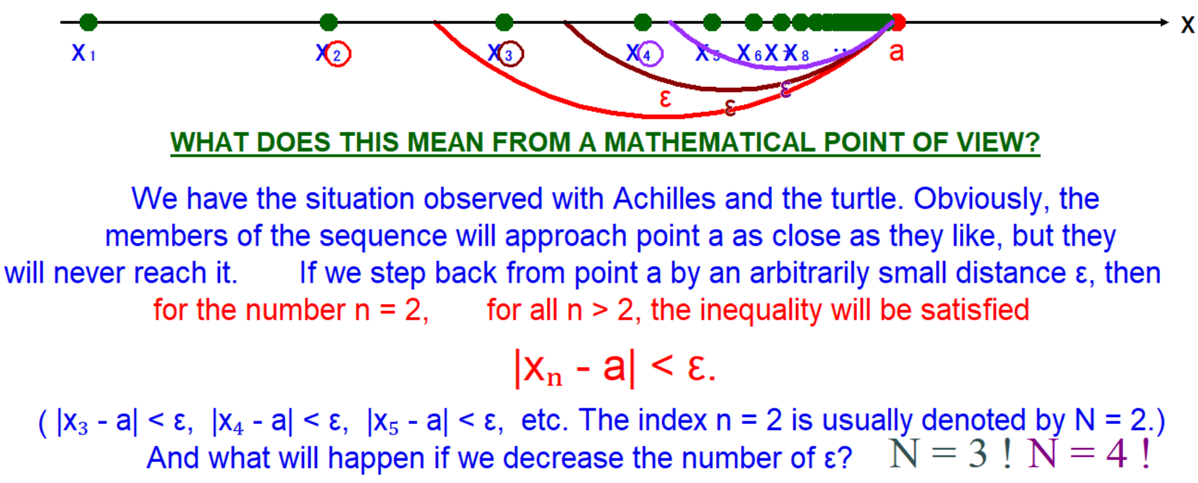

Figure 10 - Dependence of the number N on the choice of a specific ε

After all that has been studied, students are fully ready to perceive and assimilate the definition of the limit of sequence in verbal form and in the language of mathematics, which in turn removes all problems in determining the limit of a function.

3. Results and discussion

The experiment, which took place between 2021 and 2023, was conducted at the beginning of each semester during the study of the subjects "Mathematical Analysis" and "Mathematics." In order to investigate the motivational factors, interests, and individual characteristics of first-year students, representative control and experimental groups of 42 participants were formed each year, and testing was conducted to assess their level of knowledge. After a certain period, a repeated assessment was carried out - in the experimental groups, classes were conducted using CTP (computer-based teaching program), and in the control groups - in the traditional manner. As a result of the experimental research, values of indicators were obtained that characterize the degree of mastering of educational material by students, the quality of absorption of educational material in mathematics, and the formation of cognitive skills.

The leading indicators for the first criterion, which is the degree of mastery of the educational material, are the coefficient of assimilation of the volume of concepts ($\overline{K_p}$) and the coefficient of completeness of the formation of the ability to operate with concepts when solving problems ($\overline{K_y}$). These coefficients are determined using the following formula:

$\overline{K_p} = \frac{\sum_{i=1}^{n} m_i}{nm}$, where m_i – the number of concepts of the information module learned by the i-th student; m – the number of key concepts needed to be learned in a given information module; n – the number of respondents who took part in the testing.

$\overline{K_y} = \frac{\sum_{i=1}^{n} p_i}{np}$, где p_i – the number of information block tasks correctly solved by the i-th student; p – the number of tasks that needed to be solved in a given information module; n – the number of respondents who took part in the testing.

Table 1 - Dynamics of changes in the values of indicators characterizing the degree of students' mastery of educational material

Modules	Control groups		Experimental groups	
	$\overline{K_p}$	$\overline{K_y}$	$\overline{K_p}$	$\overline{K_y}$
1. The limit of the sequence	0,73	0,71	0,75	0,78
2. A function of a single variable	0,71	0,72	0,78	0,79
3. Function limit	0,72	0,68	0,77	0,71
4. Continuity of function	0,60	0,73	0,76	0,82
5. Derivative	0,67	0,65	0,83	0,76
6. Applications of the derivative	0,59	0,68	0,81	0,75

For the purpose of analysis, Microsoft Excel TP and the Data Analysis add-in were used, in conjunction with the "Paired Two-Sample t-Test for Means" function. The average number of key concepts learned in each module of the course was selected as an independent variable. As a result of this analysis, the following statistical measures were obtained:$|t_{эмп.}| = 6,3$, which significantly exceeds $t_{кр.}(0,05) = 2,02$, Therefore, we reject the null hypothesis that there are no differences. Therefore, the differences in the average values of knowledge acquisition indicators in the second sample are not random but systematic. Based on the coefficient of completeness in the formation of skills for operating with concepts, the following statistics have been obtained: $|t_{эмп.}| = 8,49$, which significantly also exceeds the critical value $t_{кр.}(0,05) = 2,02$.

The quality of learning of educational material in mathematics has been determined according to a methodology developed by the author, using a coefficient that measures the depth of understanding of connections between concepts. This indicator is calculated based on a definition of the fractal dimension (D), which is an indicator of the interdisciplinary connectedness between concepts, and is calculated using the Hurst (H) indicator, which is related to the simple ratio D + H = 2, as presented in reference [32]. A detailed description of the algorithm for calculating the Hurst indicator can be found in that reference. The final formula for calculating this indicator is:

$$= \frac{log(^{R}/_{S})}{log(^{n}/_{2})},$$

where S – standard deviation of learned concepts, R – the scope of the accumulated deviation, *n* – the number of respondents.

Table 2 - Dynamics of changes in the values of the H-Hurst index and the values of the fractal dimension indicator D

Modules	Control groups		Experimental groups	
	H	D	H	D
1. The limit of the sequence	0,5037	1,4963	0,3802	1,6198
2. A function of a single variable	0,4862	1,5138	0,4380	1,5620
3. Function limit	0,4879	1,5121	0,4116	1,5884
4. Continuity of function	0,5373	1,4627	0,5233	1,4767
5. Derivative	0,5663	1,4337	0,4527	1,5728
6. Applications of the derivative	0,4879	1,5121	0,4272	1,5690

A comparative statistical analysis of the distribution of interdisciplinary connectivity of concepts among students in the control and experimental groups has allowed us to reject the null hypothesis, which states that there are no significant differences in the average values of the indicator for interdisciplinary connectivity between the two groups. $(t_{эмп} = 4{,}66 > t_{кр}(0{,}05) = 2{,}02)$. The obtained result allows us to suggest that the practical implementation of the CTP leads to a significant increase in the fractal dimension of the content of mathematical education, and as a result, to the establishment of deep connections at various levels, enhancing the quality of assimilation of educational material in mathematics.

Bloom's taxonomy has been used to assess the development of cognitive skills, and its effectiveness has been demonstrated in numerous studies. A summary of the findings from the study is presented in Table 3 below.

Table 3 - The results of the experiment using the Bloom method

Difficulty level	Number of students					
	Control groups	Experimental groups	Control groups	Experimental groups	Control groups	Experimental groups
Memorization	39	42	37	42	40	41
Understanding	21	40	25	41	18	41
Application	17	36	18	33	15	35
Analysis	8	25	6	28	10	30
Synthesis	4	14	5	20	7	19
Score	3	10	4	12	3	13
	2021 г.		2022 г.		2023 г.	

It is clear that the experimental group outperformed the control group in terms of quantitative indicators, as most students in this group had a thorough understanding of the material under study. However, it is also true that there were some students in the experimental group who had difficulty applying knowledge in practical situations and analyzing material. This may be due to an overly childish approach on the part of these students, which may not always be possible to reverse.

As a result of the study, it has been demonstrated that CTPs with the learning feature and interactive animations generate considerable interest, contribute to the stimulation of cognitive activity, and significantly enhance the level of knowledge acquisition. Another benefit of this approach is its potential for use outside of regular school hours.

4. Conclusion

During the study, the authors have developed a computerized learning system for mathematics with animation features, which allows for the comprehensive formation of basic mathematical knowledge and ensures the effective development of cognitive skills. The developed criteria and indicators can provide an objective assessment of the dynamics of professional competence development in the teaching process, thus making a significant contribution to expanding organizational and methodological support for teaching mathematics using innovative digital technologies.An analysis of the empirical data from the study, using a range of mathematical and statistical techniques, has revealed a positive trend in the level of comprehension of key concepts and cognitive abilities in the learning of mathematics among the experimental groups, thereby validating the previous theoretical findings regarding the enhancement of mathematical ability in the context of computer-based training.

References

[1] Yaroshenko, S. N. (2021). *Formation of competitiveness of university students: professional and personal components, pedagogical conditions, diagnostics: monograph*. Chelyabinsk: Printing House Publishing House, 128 p.

[2] Konoplyansky, D. A. (2017). *Pedagogical strategy for developing the competitiveness of a university graduate*: dissertations for the degree of Doctor of Pedagogical Sciences. Kemerovo.

[3] What is digitalization of education and why is it needed? [Electronic resource]. URS: https://skillbox.ru/media/education/chto-takoe-tsifrovizatsiya-obrazovaniya-i-zachem-ona-nuzhna/ (03.04.2024)

[4] Kenzhebaeva, Z. S., Sadyrova, M. S., Mukhtar, E. S., Momynkulova, Sh. O. (2021). The use of digital technologies in the distance education system: foreign experience and Kazakhstan. *Bulletin of the Kazakh National University. Pedagogical Sciences Series*. Vol. 67. No. 2. Pp. 40-50.

[5] Kazin, F. A., Lukyanova, N. G. (2022). School today and tomorrow through the eyes of high school students. *Issues of education*. Vol. 2. Pp. 155-189.

[6] Khudenko, V. N., Stavitskaya, E. P., Maklakhova, I. S. (2020). On the features of using dynamic visualization of educational material in the study of higher mathematics. In Proceedings of the All-Russian Scientific and Practical Conference «High technologies, science and education: current issues, achievements and innovations», Penza, pp. 14-17.

[7] Neisser, U. (1981). Cognition and reality. Moscow: “Progress”, 230 p.

[8] Romanova, G. V. (2020). Digitalization of higher education: new trends and implementation experience. *Humanities*. Vol. 4. No. 52. Pp. 31-36.

[9] Technology-enabled teaching and learning at scale. A roadmap to 2030: From fi xes to foresight: Jisc and Emerge Education insights for universities and startups. Report 8 / ed. by Mario Barosevcic, Jan Lynn-Matern, Charlotte Jones. Emerge Education: Jisc. – London, Bristol, 2021.

[10] Erdem, C., Kocyigit, M. (2019). Exploring undergraduates’ digital citizenship levels: adaptation of the digital citizenship scale to Turkish. *Malaysian Online Journal of Educational Technology*. Vol. 7. No 3. Pp. 22–38.

[11] Setwyn, L. (2016). Digital downsides: exploring university students’ negative engagements with digital technology. *Teaching in Higher Education*. Vol. 21. Issue 8. Pp. 1006–1021.

[12] Lai K., Hong, K. (2015). Technology use and learning characteristics of students in higher education: Do generational differences exist? *British Journal of Education Technology*. 2015. Vol. 46. No 4. Pp. 725–738.

[13] Ivanovsky, B. G. (2021). Digitalization of higher education in Europe and Russia: advantages and risks. *Social innovations and social sciences*. Vol. 1. No. 3. Pp. 80 -95.

[14] Mayer, R. E. (2020). *Multimedia Learning.* CAMBRIDGE UNIVERSITY PRESS, 450 p.

[15] Vetlugina, N. O., Fominykh, M. V. (2021). Multimedia technologies in the context of problem modeling as a new approach to learning. *Modern problems of science and education*. No. 4. P. 35.

[16] Tikhaeva, V. V., Bgantseva, I. V., Ionkina, E. Yu., Tislenkova, I. A. (2020). Problems of self-regulated learning in a multimedia environment. *PRIMO ASPECTU*. Vol. 42. No. 2. Pp. 95-99.

[17] Shakhbanov, Sh. N. (2020). Some issues of using multimedia technologies in online distance learning for students. *Enigma*. No. 27-3. Pp. 61-65.

[18] Bondarenko, O. V. (2017). Application of multimedia technologies in the educational process of a higher educational institution. *Modern problems of science and education*. No. 3. P. 83.

[19] Tuzkova, Yu. V., Chernyavskaya, A. P. (2023). Assessing student satisfaction with learning in an electronic educational environment. *Yaroslavl Pedagogical Bulletin*. Vol. 5. No. 134. Pp. 89-100.

[20] Bogdanov, V. V. (2023). Basic terminology and issues in the development of electronic educational complexes. In Proceedings of theVI International Scientific and Practical Conference "Challenges of globalization and the development of digital society in the conditions of the new reality", Moscow, 2023, pp. 24-31.

[21] Oleinik, V. M. (2023). Models and mechanisms necessary to implement control of the learning process in computer programs, taking into account the features of interactive adaptive learning in modern features of computational mathematics. In Proceedings of the IX International Scientific and Practical Conference « Science and education in the context of global transformation », Petrozavodsk, pp. 67-80.

[22] Shpagina, A. A., Nesterova, L. E. (2021). Development and implementation of a computer training system for mastering the school course “Geometry”. In Proceedings of the XIV All-Russian scientific and practical conference with international participation «National priorities of modern Russian education: problems and prospects », Vladivostok, pp. 231-236.

[23] Zaporozhtseva A. A., Zvereva L. G. (2019). Possibilities of using information technology in the process of teaching geometry in grades 10-11. Colloquium-Journal. Vol. 16-5. No 40. Pp. 11-12.

[24] Zhabina, S. A., Milyutina, T. V. (2021). Formation of IT competencies of students through the use of hand-drawn animation in pencil2d. In Proceedings of the XV All-Russian Scientific and Practical Conference «Information technologies in the educational process of universities and schools », Voronezh, pp. 147-151.

[25] Schweigert, K. A. (2019). Creation of educational animation for visualization of processes in the study of engineering geodesy. In Proceedings of the International scientific and practical conference « Research in the field of psychology and pedagogy in modern society», Sterlitamak, January 23, pp. 243-246.

[26] Bakhmetyev, D. A. (2015). Creating an educational animated film as a way to activate the cognitive activity of students. *Bulletin of the Chelyabinsk State Pedagogical University*. No. 7. Pp. 19-23.

[27] Nazarenko, S. D. (2014). The issue of increasing the effectiveness of distance courses for distance learning students. In Proceedings of the VII international scientific and practical conference «New information technologies in education», Ekaterinburg. March 11-14, pp. 255-259.

[28] Zayats, T. A. (2020). Some aspects of the organization of controlled independent work of students. In 20th international scientific and practical conference. New information technologies in education (pp. 236-238), Moscow, February 4-5.

[29] Kozel, A. A. (2021). Mobile technologies in the educational process of higher educational institutions: classification and experience of use. In Proceedings of the II International Scientific and Practical Conference «Language. Society», Tomsk, pp. 245-248.

[30] Makarova, N. P. (2023). On resource support for remote controlled independent work of students. In Materials of the international scientific and practical conference dedicated to the 65th anniversary of the IMF «Transformation of mechanics, mathematics and IT education in the conditions of digitalization», Minsk, pp. 69-72.

[31] Chernyakova, E. A. (2023). Presentation as a type of controlled student work. In Collection of scientific articles «Linguistics, intercultural communication and translation problems», Gomel, pp. 115-119.

[32] Dvoryatkina, S. N. Modification of methods for diagnosing the quality of students' assimilation of educational mathematical material in the context of a fractal approach based on ICT. *Modern Information Technologies and IT-education*. 2015. Vol. 11. № 1. Pp. 239-243.

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