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INDICATORS OF EFFECTIVENESS IN DEVELOPING THE PROFESSIONAL COMPETENCIES OF ENERGY STUDENTS THROUGH ADAPTIVE EDUCATION TECHNOLOGIES BASED ON ARTIFICIAL INTELLIGENCE (RESPONDENTS IN QUANTITY AND PERCENTAGE)

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Abstract
This scientific article analyzes the final results and average academic performance of the conducted experiment to determine the effectiveness indicators for developing the professional competencies of energy students through adaptive educational technologies based on artificial intelligence using the Student's t-test and Pearson's $\chi 2$ mathematical-statistical method.

Keywords: Artificial intelligence, adaptive educational technologies, energy direction, student, Pearson's, mathematical statistics, competencies, hypothesis, variational series.

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Introduction

Nowadays, digitalization and artificial intelligence technologies are playing a crucial role in transforming global education systems. The process of training students in technical fields, such as engineering and especially electrical engineering, cannot be limited to traditional teaching methods and ensure the simultaneous effective and comprehensive development of their theoretical knowledge and practical skills. Therefore, educational technologies based on artificial intelligence allow for the formation of students' individual learning trajectories, the objective assessment of knowledge and practical skills, and the identification of areas facing difficulties in the educational process [1].

The rapid development of the modern energy sector and the increasing demand for the efficiency of electrical networks require engineering personnel trained in higher educational institutions to possess high professional competencies. Furthermore, the analysis of the educational process through artificial intelligence tools and flexible learning models allow for the dynamic adaptation of educational content and methods depending on the student's individual level of knowledge and pace of development. This is due to the possibility of analyzing the scientific foundations and developing an integrated model for the effective training of students in the field of power supply using artificial intelligence tools, which is of great importance in improving the quality of education and strengthening human resource potential in higher education institutions [2].

The processes of digitalization and intellectualization have a significant impact on the content of engineering education, necessitating a revision of traditional teaching methods when training students in the field of power supply. Artificial intelligence-based educational models allow for a comprehensive assessment of students' theoretical knowledge and practical skills, the analysis of their learning activity dynamics, and the formation of individual learning trajectories. Through such an approach, students gradually master professional tasks such as calculating electrical networks, determining load distribution, and assessing energy efficiency. For example, in the first case, the student is provided with an intelligent simulation environment using artificial intelligence, in which he performs the task of modeling load distribution and determining the power balance at a 110/35 kV power plant. The system provides full feedback on the student's calculations and decisions, identifies errors, and indicates which

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knowledge or practical skills are missing. Furthermore, the student's laboratory sessions are individualized through an adaptive learning system. If the student's ability to calculate transformer efficiency is insufficiently developed, the system will automatically provide additional theoretical and practical tasks, allowing for the gradual reinforcement of their knowledge and skills. Learning analytics and big data technologies are also used [3-5].

Table 1The level of professional competencies of energy students at the stage preceding the implementation of adaptive educational technologies based on artificial intelligence

№	Regions	Quantity	Group	Before the experiment			After the experiment		
				Upper	Medium	Lower	Upper	Medium	Lower
1	Kashkadarya region	69	experience	21 / 31	27 / 39	21 / 30	41 / 60	19 / 27	9 / 13
		64	supervision	19 / 30	23 / 36	22 / 34	23 / 36	22 / 35	19 / 29
2	Jizzakh region	51	experience	17 / 33	18 / 35	16 / 32	29 / 57	15 / 29	7 / 14
		50	supervision	15 / 30	17 / 34	18 / 36	18 / 36	16 / 32	16 / 32
3	Fergana Region	42	experience	13 / 31	15 / 36	14 / 33	24 / 57	12 / 28	6 / 15
		44	supervision	14 / 32	15 / 34	15 / 34	16 / 36	14 / 32	14 / 32
4	Bukhara region	25	experience	9 / 36	8 / 32	8 / 32	12 / 48	9 / 36	4 / 16
		25	supervision	8 / 32	9 / 36	8 / 32	9 / 36	8 / 32	8 / 32
	Total:	**187**	experience	**60 / 32**	**68 / 36**	**59 / 32**	**106 / 57**	**55 / 29**	**26 / 14**
		183	supervision	**56 / 31**	**64 / 35**	**63 / 34**	**66 / 36**	**60 / 33**	**57 / 31**

Based on the results of the above analysis, the level of professional competencies of energy students at the stage preceding the introduction of adaptive educational technologies based on artificial intelligence is summarized in the table below. These indicators serve to assess the initial state and identify subsequent changes.

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Table 2.Level of effectiveness in developing the professional competencies of energy students through adaptive educational technologies based on artificial intelligence at the beginning of the experimental work (number of respondents and percentage).

Group	Number of respondents	Proficiency indicators		
		Upper	Medium	Lower
experience	187	60 / 32	68 / 36	59 / 32
supervision	183	56 / 31	64 / 35	63 / 34

Based on the results of the table, the average mastery in the final results of the experiment to determine the effectiveness indicators of the development of professional competencies of students in the field of energy through adaptive educational technologies based on artificial intelligence was analyzed using Student's t-test and Pearson's $\chi 2$ mathematical-statistical method. 370 respondents participated in the experimental process, including 187 students in the experimental group and 183 students in the control group.

Based on the essence of the problem, two empty sets are given. This empty set includes the average scores of the respondents in the experimental group and the control group. Grades are considered the mean distribution. In this case, the conditions for the average distribution to conform to the normal distribution are simple. The average distribution is performed.

In the tables presented above, hypothesis N1, which demonstrates the effectiveness of mastering the skills of respondents in the experimental and control groups, and hypothesis N0, which is opposite to it, were identified. We define the knowledge and skills acquisition indicators in the experimental group and the number of respondents accordingly as Xini, and similarly, the control group as Yjnj. After this, the following statistically grouped variation series are formed. We enter a high level of assessment as 3 points, a medium level as 2 points, and a low level as 1 point.

Learning level in the experimental group:

$$(1)\begin{cases} X_i & 3; \quad 2; \quad 1; \\ n_i & 60; \quad 68; \quad 59; \qquad n = \sum_{i=1}^{3} n_i = 187 \end{cases}$$

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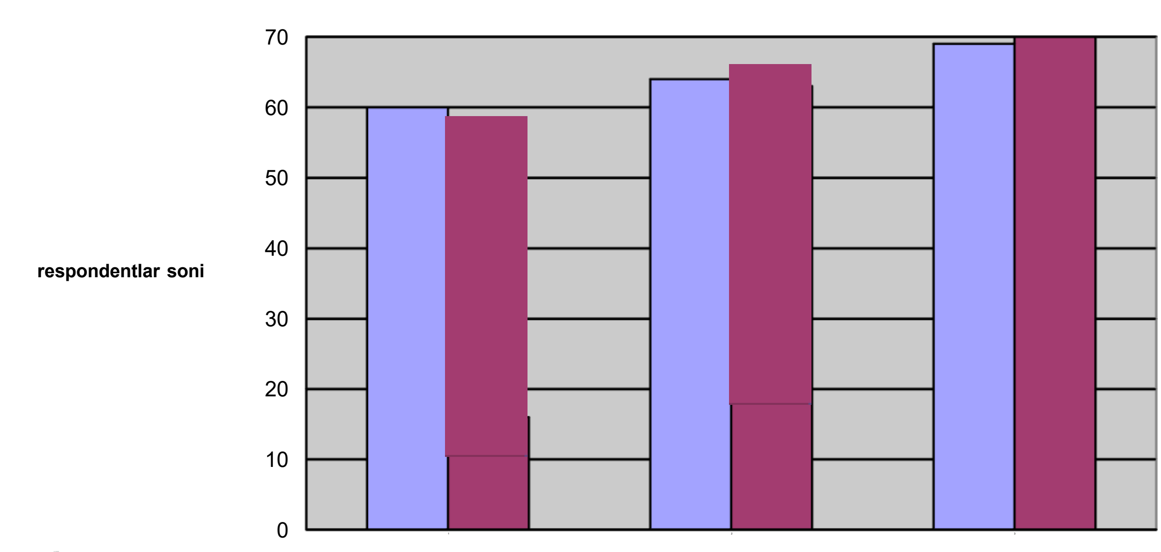
Nazorat guruhidagi o‘rganish darajasi:

$$(2)\begin{cases} Y_i & 3; \quad 2; \quad 1; \\ m_i & 56; \quad 64; \quad 63; \end{cases} \qquad m=\sum_{i=1}^{3} m_i = 183$$

We illustrate this with a diagram as follows:



	1	2	3
Nazorat guruhi	63	64	56
Tajriba guruhi	59	68	60

Figure 1. Indicators at the beginning of the experimental work

To simplify statistical analysis, appropriate statistical probability formulas for the frequency (frequency) of the variational series above are used. $p_i=\frac{n}{n_i}$ va $q_j=\frac{m}{m_i}$ we calculate using .

$$(3)\begin{cases} X_i & 3; \quad 2; \quad 1; \\ n_i & 0{,}32; \quad 0{,}36; \quad 0{,}32; \end{cases} \qquad \sum_{i=1}^{3} p_i = 1$$

$$(4)\begin{cases} Y_i & 3; \quad 2; \quad 1; \\ m_i & 0{,}31; \quad 0{,}35; \quad 0{,}34; \end{cases} \qquad \sum_{i=1}^{3} q_j = 1$$

At the beginning of the statistical analysis, we calculate the average mastery of the results in the experimental and control groups. Then we compare the results. This result showed that the average mastery indicators are as follows:

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$$\overline{X} = \sum_{i=1}^{n=3} P_i X_i = 0{,}32 \cdot 3 + 0{,}36 \cdot 2 + 0{,}32 \cdot 1 = 0{,}96 + 0{,}72 + 0{,}32 = 2$$

$$\text{Foizda} \qquad \overline{X}\% = \frac{2}{3} \cdot 100\% = 66{,}7\%$$

$$\overline{Y} = \sum_{i=1}^{n=3} q_j Y_j = 0{,}31 \cdot 3 + 0{,}35 \cdot 2 + 0{,}34 \cdot 1 = 0{,}93 + 0{,}7 + 0{,}34 = 1{,}97$$

$$\text{Foizda} \qquad \overline{Y}\% = \frac{1{,}97}{3} \cdot 100\% = 65{,}7\%$$

Thus, if we calculate the average academic performance of the respondents in the experimental and control groups, it is 66.7% vs. 65.7% vs. 1%. At the same time, the average performance of the experimental group is 1% higher than that of the control group. This, in turn, $\frac{2}{1{,}97\%} = 1{,}02$ is equal to . However, this figure is too low to be effective. This shows that no efficiency was achieved at the beginning of the experiment.

Let us now consider what results were achieved at the end of the experiment.

Table 3.At the end of the experimental work, the level of effectiveness in developing the professional competencies of energy students using adaptive educational technologies based on artificial intelligence (number of respondents and percentage)

Group	**Number of respondents**	**Proficiency indicators**		
		Upper	**Medium**	**Lower**
experience	187	106 / 57	55 / 29	26 / 14
supervision	183	66 / 36	60 / 33	57 / 31

Mastery indicators in the experimental group:

$$(5)\begin{cases} X_i & 3; & 2; & 1; \\ n_i & 106; & 55\ ; & 26; \end{cases} \qquad n = \sum_{i=1}^{3} n_i = 187$$

Mastery indicators in the control group:

$$(6)\begin{cases} Y_i & 3; & 2; & 1; \\ m_i & 66; & 60; & 57; \end{cases} \qquad m = \sum_{i=1}^{3} m_i = 183$$

It looks like this diagram:

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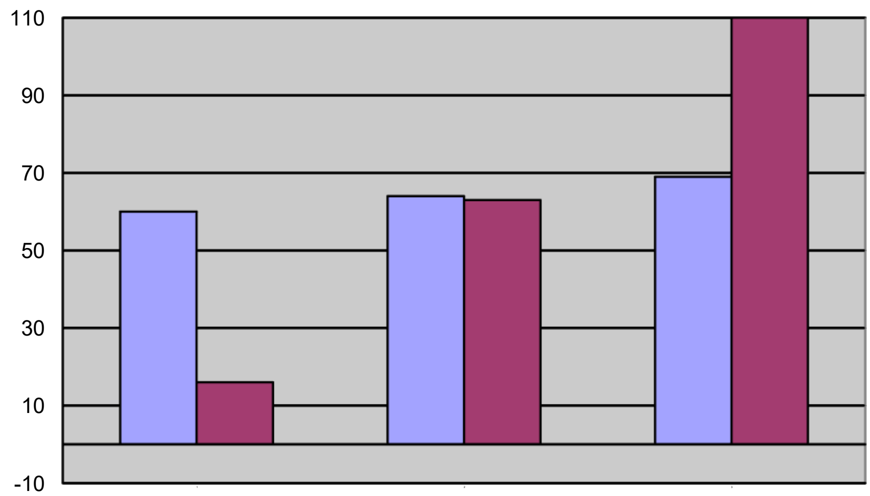

	1	2	3
Nazorat guruhi	57	60	66
Tajriba guruhi	26	55	106

Figure 2. At the end of the experimental work

To facilitate statistical analysis, appropriate statistical probability formulas are used to determine the frequency (frequency) of the variation series $p_i = \frac{n}{n_i}$ va$q_j = \frac{m}{m_i}$ let's calculate based on .

$$(7)\begin{cases} X_i & 3; & 2; & 1; \\ n_i & 0{,}57; & 0{,}29; & 0{,}14; \end{cases} \qquad \sum_{i=1}^{3} p_i = 1$$

$$(8)\begin{cases} Y_i & 3; & 2; & 1; \\ m_i & 0{,}36; & 0{,}33; & 0{,}31; \end{cases} \qquad \sum_{i=1}^{3} q_j = 1$$

At the beginning of the statistical analysis, we calculate the average mastery of the results in the experimental and control groups. Then we compare the results. The result showed that the average mastery indicators are as follows:

$$\overline{X} = \sum_{i=1}^{n=3} P_i X_i = 0{,}57 \cdot 3 + 0{,}29 \cdot 2 + 0{,}14 \cdot 1 = 1{,}71 + 0{,}58 + 0{,}14 = 2{,}43$$

Foizda $\quad \overline{X}\% = \frac{2{,}43}{3} \cdot 100\% = 81\%$

$$\overline{Y} = \sum_{i=1}^{n=3} q_j Y_j = 0{,}36 \cdot 3 + 0{,}33 \cdot 2 + 0{,}31 \cdot 1 = 1{,}08 + 0{,}66 + 0{,}31 = 2{,}05$$

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$$\text{Foizda} \qquad \overline{Y}\% = \frac{2{,}05}{3} \cdot 100\% = 68{,}3\%$$

Thus, if we calculate the average academic performance of the respondents in the experimental and control groups, it is 81% versus 68.3% versus 12.7%. At the same time, we see that the average academic performance of the experimental group increased by 12.7% compared to the control group. This, in turn, $\frac{81\%}{12{,}7\%} = 6{,}38$ means times more. In this case, i.e., efficiency was achieved after the experiment.

In order to determine the possibility of errors in the process of learning, we first determine whether there are standard and standard errors.

$$S_x^2 = \sum_{i=1}^{n=3} P_i X_i^2 - (\overline{X})^2 = 0{,}57 \cdot 3^2 + 0{,}29 \cdot 2^2 + 0{,}14 \cdot 1^2 - 2{,}43^{\quad 2}$$

$$= 0{,}57 \cdot 9 + 0{,}29 \cdot 4 + 0{,}14 \cdot 1 - 5{,}9049 =$$

$$= 5{,}13 + 1{,}16 + 0{,}14 - 5{,}9049 = 6{,}43 - 5{,}9049 = 0{,}5251$$

$$S_y^2 = \sum_{i=1}^{n=3} q_j Y_j^2 - (\overline{Y})^2 = 0{,}36 \cdot 3^2 + 0{,}33 \cdot 2^2 + 0{,}31 \cdot 1^2 - 2{,}05^2$$

$$= 0{,}36 \cdot 9 + 0{,}33 \cdot 4 + 0{,}31 \cdot 1 - 4{,}2025 =$$

$$= 3{,}24 + 1{,}32 + 0{,}31 - 4{,}2025 = 4{,}87 - 4{,}2025 = 0{,}6675$$

$$S_x = \sqrt{0{,}5251} = 0{,}72. \qquad\qquad S_y = \sqrt{0{,}6675} = 0{,}82.$$

Furthermore, the standard error of the control group was greater than that of the experimental group, i.e., 0.82 > 0.72. To demonstrate this more clearly, we will calculate the accuracy of the mean values for both statistical responses using the coefficients of variation, i.e., the formula Cx and Cu:

$$C_x = \frac{S_x}{\sqrt{n} \cdot \overline{x}} \cdot 100\% = \frac{0{,}72 \cdot 100\%}{\sqrt{187} \cdot 2{,}43} = \frac{72\%}{13{,}7 \cdot 2{,}43} = \frac{72\%}{33{,}3} = 2{,}16\% \approx 2\%$$

$$C_y = \frac{S_y}{\sqrt{n} \cdot \overline{y}} \cdot 100\% = \frac{0{,}82 \cdot 100\%}{\sqrt{183} \cdot 2{,}05} = \frac{82\%}{13{,}5 \cdot 2{,}05} = \frac{82\%}{27{,}68} = 2{,}96\% \approx 3\%$$

Consequently, the accuracy of the standard error in the control group is two units higher than in the experimental group.

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Now, considering the similarity of the unknown means of the two populations, let's test the null hypothesis based on Student's t-test:

$$H_0: \mu = \mu_y$$

We calculate this as follows:

$$T_{x,y} = \frac{\overline{x} - \overline{y}}{\sqrt{\frac{S_x^2}{n} + \frac{S_y^2}{m}}} = \frac{2,43 - 2,05}{\sqrt{\frac{0,5251}{187} + \frac{0,6675}{183}}} = \frac{0,38}{\sqrt{0,0028 + 0,0036}} = \frac{0,38}{\sqrt{0,0064}} = \frac{0,38}{0,08} = 4,75$$

Based on Student's t-test, we calculate the degrees of freedom using the following formula:

$$K_{x,y} = \frac{\left(\frac{S_x^2}{n} + \frac{S_y^2}{m}\right)^2}{\frac{\left(\frac{S_x^2}{n}\right)^2}{n-1} + \frac{\left(\frac{S_y^2}{m}\right)^2}{m-1}} = \frac{\left(\frac{0,5251}{187} + \frac{0,6675}{183}\right)^2}{\frac{\left(\frac{0,5251}{187}\right)^2}{186} + \frac{\left(\frac{0,6675}{183}\right)^2}{182}} = \frac{(0,0028 + 0,0036)^2}{\frac{(0,0028)^2}{196} + \frac{(0,0036)^2}{192}} =$$

$$= \frac{(0,0064)^2}{\frac{0,00000784}{186} + \frac{0,000013}{182}} = \frac{0,000040}{0,000000042 + 0,000000071} = \frac{0,000040}{0,00000011} = 372,36$$

if we take the significance level of the statistical criterion for this probability as 0.05, then p = 1 - 0.95 and the degree of freedom is k = 372.36. The critical point of the two-sided test from the Student's table:

$$t_{1-\frac{(1-p)}{2}}(k) = t_{1-\frac{(1-0,95)}{2}}(372,36) = t_{0,975}(372,36) = 1,97$$

This means that the sample value of the statistic is greater than the critical point. Student's t-test:

$T_{x,y}$= 4,75 > 1,97 will have a large minority.

Consequently, the null hypothesis N0 regarding the equality of principal averages has been rejected. The average performance indicators of the experimental group were higher than those of the control group, and they do not overlap.

We see a contradiction in our view of the teaching style in the experimental and control groups.

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$$K_0 : F_x = F_u$$

In this case, the distribution of the two populations coincides.

At the given α significance level N1: - to test the hypothesis that the population is normally distributed, we first calculate the theoretical frequencies and then Pearson's suitability criterion - X squared based on systems (5) and (6) using the following formula:

$$X^2_{n,m} = \frac{1}{n\cdot m}\sum_{i=1}^{3}\frac{(nm_i - mn_i)^2}{m_i+n_i} = \sum_{i=1}^{3}\frac{(m_i-n_i)^2}{m_i+n_i}.$$

Based on formula $X^2_{n,m}$:

$$X^2_{n,m} = \frac{(106-66)^2}{106+66} + \frac{(55-60)^2}{55+60} + \frac{(26-57)^2}{26+57} = \frac{1600}{172} + \frac{25}{115} + \frac{961}{83} =$$

$$x = 9{,}3 + 0{,}22 + 11{,}57 = 21{,}09$$

ga teng.

According to this criterion, the degrees of freedom are ν = 3 - 1 = 2, and we find the critical point within the table of the X-squared distribution. confidence probability for r = 0.95.

$$t_{0,95}(V) = t_{0,95}(2) = 6 \quad \text{ga teng}$$

We construct a right-hand critical region because the one-sided criterion rejects the null hypothesis "more resolutely" than the two-sided criterion. The right-sided critical region is .

$$X^2_{n,m} = 21{,}09 > 6 = t_{0,95}$$

From this, the null hypothesis was rejected because the X-square distribution is greater than the critical point.

Now we look for a specific interval to find the evaluation effectiveness indicator:

$$\Delta_x = t_\gamma \cdot \frac{S_x}{\sqrt{n}} = 1{,}96 \cdot \frac{0{,}72}{\sqrt{187}} = 1{,}96 \cdot \frac{0{,}72}{13{,}7} = \frac{1{,}4112}{13{,}7} \approx 0{,}1$$

$$\Delta_y = t_\gamma \cdot \frac{S_y}{\sqrt{n}} = 1{,}96 \cdot \frac{0{,}82}{\sqrt{183}} = 1{,}96 \cdot \frac{0{,}82}{13{,}5} = \frac{1{,}6072}{13{,}5} \approx 0{,}12$$

equals . If we find the confidence interval for the experimental group from the results obtained:

$$\overline{\text{X}} - t_{\text{кр}} \cdot \frac{S_x}{\sqrt{n}} \le a_{\text{x}} \le \overline{\text{X}} + t_{\text{кр}} \cdot \frac{S_x}{\sqrt{n}}$$

for experimental group:

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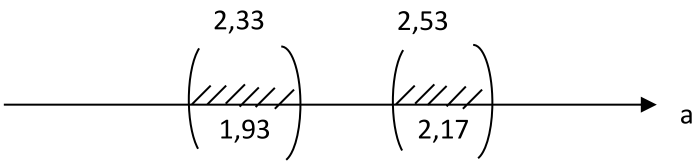
$2{,}43 - 0{,}1 \le a_x \le 2{,}43 + 0{,}1 \qquad\qquad 2{,}33 \le a_x \le 2{,}53$

Confidence interval for the control group:

$$\bar{Y} - t_{кр} \cdot \frac{S_y}{\sqrt{n}} \le a_y \le \bar{Y} + t_{кр} \cdot \frac{S_y}{\sqrt{n}}$$

$2{,}05 - 0{,}12 \le a_y \le 2{,}05 + 0{,}12 \qquad\qquad 1{,}93 \le a_y \le 2{,}17$

To represent this geometrically:



It should be noted that with a significance level of x=0.05, the average grades in the experimental group are higher than the average grades in the control group, and the intervals do not overlap. Thus, based on mathematical and statistical analysis, it was revealed that a good result had been achieved.

Based on the above results, we shall calculate the quality indicators of the experimental work.

We know $\bar{X}$=2,43; $\bar{Y}$=2,05; $\Delta_x = 0{,}1$; $\Delta_y = 0{,}12$; equals.

Based on this, quality indicators:

$К_{усб} = \frac{(\bar{X} - \Delta_x)}{(\bar{Y} + \Delta_y)} = \frac{2{,}43 - 0{,}1}{2{,}05 + 0{,}12} = \frac{2{,}33}{2{,}17} = 1{,}07 > 1;$

$К_{бдб} = (\bar{X} - \Delta_x) - (\bar{Y} - \Delta_y) = (2{,}43 - 0{,}1) - (2{,}05 - 0{,}12) = 2{,}33 - 1{,}93 = 0{,}4 > 0;$

From the final results, it is necessary to know that the evaluation criterion for the effectiveness of the experimental work is greater than one, and the level of knowledge is greater than zero. Thus, we can see that the mastery in the experimental group is higher than in the control group.

Conclusion

The final results of the experimental work aimed at developing the professional competencies of energy students through adaptive educational technologies based on artificial intelligence showed high efficiency based on statistical analysis. The obtained data confirmed that the adaptive learning model had a

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positive impact on the significant improvement of students' knowledge, skills, and abilities.

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