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Even and Odd Functions
Non-Standard Lessons in School Mathematics

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Abstract: This paper presents information on increasing the effectiveness of educational activities using the methods "Even-Even Interaction" and "Even or Odd." During the educational process, methods that promote the formation of basic competencies among students in the assessment of their knowledge are introduced, including methods to develop students' creative thinking in the context of information technology, improve their observational skills, enhance their ability to select information, teach them to identify errors and express opinions, and provide teachers with a way to assess students' knowledge are broadly utilized.

Keywords: Function, even function, odd function, trigonometric function, neither even nor odd function, graph of an even function, “Even-Even Interaction” method, “Even or Odd” method.

Introduction. In today's world, one of the requirements for organizing education is to achieve high results in a short time without excessive mental and physical effort. Delivering specific theoretical knowledge to students in a short period, forming skills and competencies related to certain activities, as well as controlling students' activities and evaluating the level of knowledge, skills, and competencies acquired by them requires high pedagogical mastery and a new approach to the educational process.

Based on these considerations, we as teachers must be more responsible. Interactivity involves mutual activity, movement, and influence, occurring in the communication between students and teachers. The main goal of the interactive method is to create the most favorable conditions for the educational process, allowing students to think actively and freely. This article provides some reflections and methodological recommendations on teaching the topic "Even and Odd Functions" known from the Mathematics course in general education schools.

2. Main Part. The topic "Even and Odd Functions," which is familiar from the school mathematics curriculum, follows the topic "Growth and Decrease of Functions." Students will not encounter problems in understanding and mastering the new topic only if they know what a function is, how to find the function's domain, and the concepts of growth and decrease of functions.

“Even-Even Interaction” method

Encouraging students sitting next to each other on a particular topic to engage in dialogue, exchange ideas, and listen to some of their peers.

Pair Work Method in Mathematics Lessons

For the topic of functions, students sitting next to each other can be given a task (or separate tasks) and invited to work together to solve the problems presented in the task, followed by sharing and evaluating the solutions.

In some cases, students may take turns posing questions (problems) to each other. In such instances, the response (solution) to the question must be listened to (checked) and evaluated by the student who posed the question.

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Care should be taken when selecting the topic for pair work. This topic should be well comprehended by the majority, or else the work in pairs may not progress effectively.

Examples of assignments:

A) Each student should create 3 functions related to the topic "Function" within 1 minute and find the domain of each function, then exchange their work with their partner. After 3 minutes, they should return to the examples and check the answers within 1 minute, evaluating them afterward.

New Topic Explanation :

Let's consider $y(x)$ function and determine whether it is even or odd. First, we will explain the concepts of even and odd functions.

Definition 1: If function $y(x)$ is called an even function if for any x in its domain, the following condition holds:

$$y(x) = y(-x).$$

For example, the functions $cos(x)$ and x^2, x^4, x^6 are considered even functions.

Example 1: Determine whether the function $f(x) = x^4+x^6 - x^8$is odd or even.

Solution:We have:

$f(-x) = (-x)^4+(-x)^6 - (-x)^8 = x^4+x^6 - x^8$

Since $f(-x)$ does not equal $f(x)$ or $-f(x)$, the function $f(x)$ is neither even nor odd.

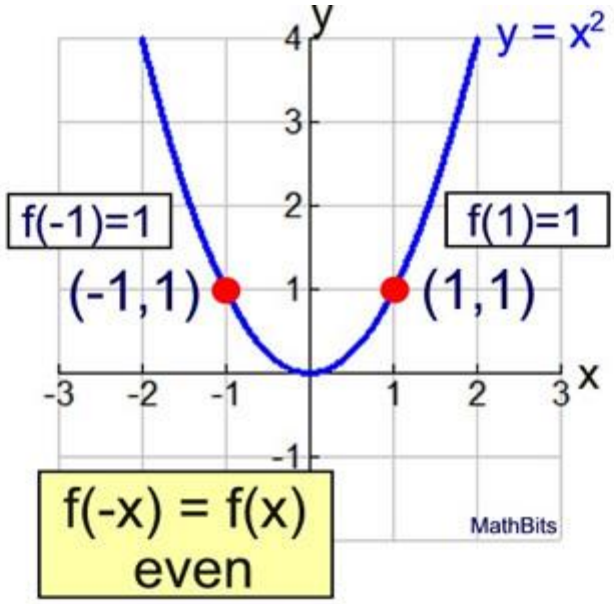

Figure 1:Graph of an even function (the graph of $y = x^2$).

The trigonometric function cos(x) is also an even function.

$$f(x) = \cos(-x) = \cos x$$

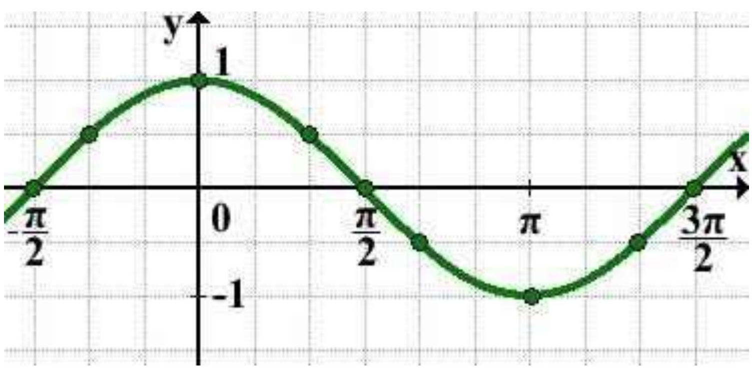

Figure 2:Graph of the cos(x) function.

Definition 2: If function $y(x)$ is called an odd function if for any x in its domain, the following condition holds:

$$y(x) = -y(-x).$$

For example, the functions sin(x) and $x^3, x^5, x^{11}$are considered odd functions.

Example 2: Check if the function $f(x) = x^7 + x^3 + x^5$is odd or even.

Solution:

$$f(-x) = (-x)^7 + (-x)^3 + (x)^5 = -(x^7 + x^3 + x^5) = -f(x)$$

Since $f(-x) = -f(x)$, the function $f(x)$ is odd.

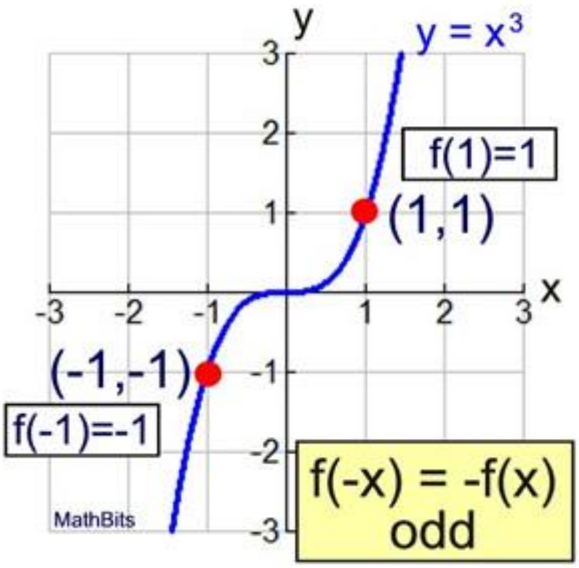

Figure 3: Graph of an odd function (the graph of $y = x^3$).

The trigonometric function sin(x) is an odd function.

$$f(x) = \sin(-x) = -\sin x$$

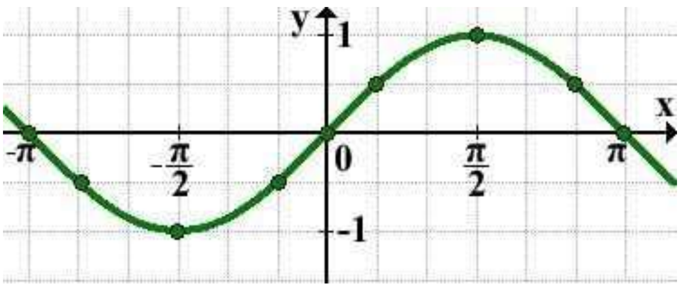

Figure 4: Graph of the sin(x) function.

The domains of even and odd functions are symmetric with respect to the coordinate axes. There are also functions that do not exhibit the properties of being even or odd, and these functions are referred to as neither even nor odd. In fact, most functions are neither odd nor even.

For example, the function $f(x) = x^2 - x + 1$ is neither odd nor even.

$$f(-x) = (-x)^2 - (-x) + 1 = x^2 + x + 1$$

This means that both oddness and evenness properties do not hold.

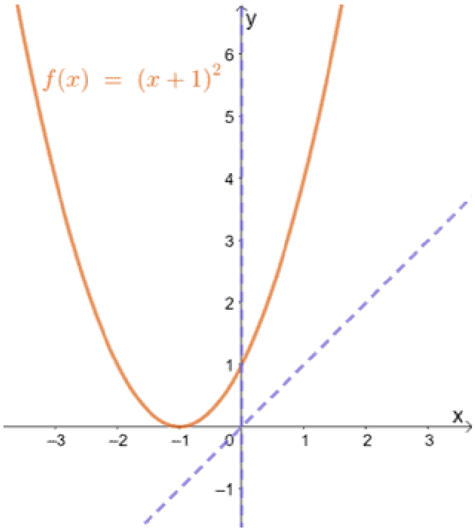

Figure 5: Graph of a function that is neither odd nor even

(the graph of $f(x) = (x+1)^2$)

Example 3: Determine if the function $y = x^8 + x^5$ is odd or even.

Since $y(-x) = (-x)^8 + (-x)^5 = x^8 - x^5 = -(x^5 - x^8)$ the function is even.

Example 4:Determine if the function $y = \frac{3}{x^3} + \sqrt[3]{x}$ is odd or even.

$$y(-x) = \frac{3}{(-x)^3} + \sqrt[3]{(-x)} = -\frac{3}{x^3} - \sqrt[3]{x} = -(\frac{3}{x^3} + \sqrt[3]{x})$$

Hence, since the condition holds, the function is odd.

Example 5: Determine if the function $f(x) = \frac{11}{\sqrt[4]{(x)}} + x^4 + \sqrt[2]{x}$ is odd or even.

$$f(-x) = \frac{11}{\sqrt[4]{(-x)}} + (-x)^4 + \sqrt[2]{(-x)} = \frac{11}{\sqrt[4]{x}} + x^4 + \sqrt[2]{x} = (\frac{11}{\sqrt[4]{(x)}} + x^4 + \sqrt[2]{x})$$

Thus, since the condition holds, the function is even.

Example 6: Using symmetry, draw the graph of the even function.

$$y = |x|$$

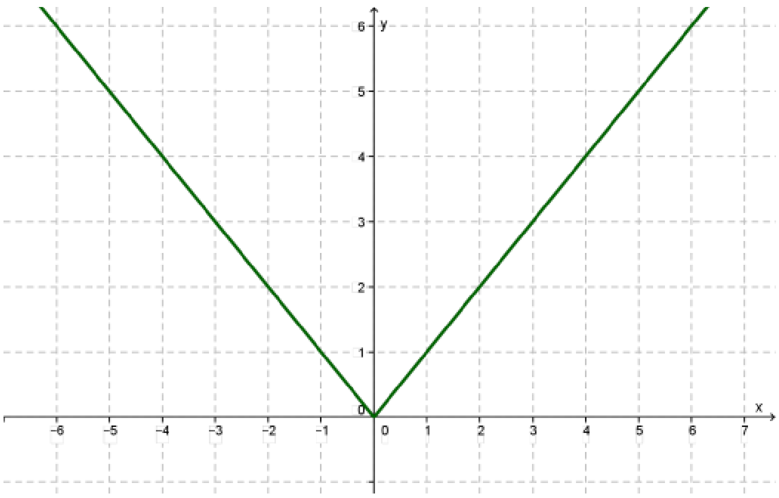

Figure 6: Graph of the function $y = |x|$

Example 7: $f(x) = x|x| + 7x$

$$f(-x) = -x|-x| + 7(-x) =$$
$$= -x|x| - 7x =$$
$$= -(x|x| + 7x)$$

Since the condition is satisfied, this complex function is also odd.

Example 8: (An interesting Olympiad problem) Solve the system for real numbers.

$$+\begin{cases} x^4 + 2y^3 - x = -\frac{1}{4} + 3\sqrt{3} \\ y^4 + 2x^3 - y = -\frac{1}{4} - 3\sqrt{3} \end{cases}$$

Solution:To solve this system, we will first add both equations together.

$$+\begin{cases} x^4 + 2y^3 - x = -\frac{1}{4} + 3\sqrt{3} \\ y^4 + 2x^3 - y = -\frac{1}{4} - 3\sqrt{3} \end{cases}$$

$$x^4 + y^4 + 2x^3 + 2y^3 - x - y = -\frac{1}{2}$$

Next, we isolate the variable on the left side of the equation, splitting the equal part.

$$x^4 + 2x^3 - x + \frac{1}{4} + y^4 + 2y^3 - y + \frac{1}{4} = 0$$

$$(x^2 + x)^2 - (x^2 - x) + \frac{1}{4} + (y^2 + y)^2 - (y^2 - y) + \frac{1}{4} = 0$$

Next, we simplify the resulting expression.

$$(x^2 + x - \frac{1}{2})^2 + (y^2 + y - \frac{1}{2})^2 = 0$$

$$\begin{cases} x^2 + x - \frac{1}{2} = 0 \\ y^2 + y - \frac{1}{2} = 0 \end{cases}$$

We solve each equation separately and then write down the general solution.

$$x^2 + x - \frac{1}{2} = 0 \; y^2 + y - \frac{1}{2} = 0$$

$$x_{1,2} = \frac{-1 \pm \sqrt{3}}{2} \; y_{1,2} = \frac{-1 \pm \sqrt{3}}{2}$$

After checking, we find that the solution is valid: $(x; y) = (\frac{-1-\sqrt{3}}{2}; \frac{-1+\sqrt{3}}{2})$.

Example 9: (Interesting Olympiad problem) Find all functions that satisfy the following condition.

$$f: Z \to Z$$
$$7f(x) = 3f\big(f(x)\big) + 2x$$

Solution: First, let's introduce notations $f(x) = g(x) + 2x$. We substitute our notations into the above function and simplify it.

$$7f(x) = 7(g(x) + 2x) = 3f(g(x) + 2x) + 2x == 3(g(g(x) + 2x) + (g(x) + 2x) * 2) + 2x$$
$$7g(x) + 14x = 3g(g(x) + 2x) + 6g(x) + 14x$$
$$g(x) = 3g(g(x) + 2x)$$
$$\frac{g(x)}{3} \to \frac{g(g(x) + 2x)}{3} \to \frac{g(x)}{3^2} \to \cdots \to g(x)/3^n$$

This results in the function being divisible by 3, and so forth, which leads to the conclusion that any integer n will satisfy the condition.

n$\in N \to g(x) \equiv 0$.

$$f(x) = g(x) + 2x$$
$$f(x) = 2x$$

Thus, the function can be expressed as $f(x) = 2x$ where k is an integer.

To reinforce the new topic, we will use the following method: **"Even or Odd"** method.

We will put key-shaped cards with several functions written on them on the board. On one side of the board, we will attach locks labeled with even and odd numbers.

Pupils will take turns going to the board, drawing cards, and determining if the function written on it is even or odd. If the answer is correct, the card is placed back. If the function is even, it goes to the lock labeled "even", and if it's odd, it goes to the lock labeled "odd". In other words, the key will unlock the corresponding lock.

An incorrect answer will result in losing points, and the lock will remain closed[7-20].

Figure 7: Samples of cards from the "Even or Odd" method.

This is the mechanism for carrying out experimental testing activities.

The experiment was conducted at the 12th school in the Olot district of Bukhara region. Parallel classes with similar levels of achievement were selected and divided into experimental and control classes accordingly. The assessment criteria for the lessons conducted in the control and experimental classes were the same, and the following results were obtained:

Class Type: Control and Experimental. Number of Classes: 2

Stage of Experiment and Academic Year	Educational school	Number of Students		Degree of mastery	In Experimental Class (9A)	In Control Class (9B)
		In Experimental Class (9A)	In Control Class (9B)			
2024 Academic Year	Olot District, 12th School	28	19	Highest (Excellent)	15 (53%)	8 (42%)
				High (Good)	12 (43%)	8 (42%)
				Average (Satisfactory)	1 (4%)	3 (16%)

The students' compliance with state educational standards was taken into account. In order to determine the effectiveness of teaching Mathematics through new non-standard lessons based on experimental testing, the final questions, tests, and results of generalized activities obtained from students were analyzed both qualitatively and quantitatively.

The analysis of the experimental tests utilized mathematical-statistical methods, which are among the scientific research methods in pedagogy.

The following table shows the changes in the dynamics of students' knowledge levels during the teaching process based on non-standard lessons (in number and percentage).

Indicators of students' skills and competencies formed in Mathematics using non-standard lessons.

Stage of Experiment and Academic Year	Educational school	Degree of mastery	At the beginning of the experiment.		At the end of the experiment.	
			In Experimental Class	In Control Class	In Experimental Class	In Control Class
2024 Academic Year	Olot District, 12th School	Highest (Excellent)	6 (21%)	4 (21%)	15 (53%)	8 (42%)
		High (Good)	10 (36%)	6 (32%)	12 (43%)	8 (42%)
		Average (Satisfactory)	12 (43%)	9 (47%)	1 (4%)	3 (16%)

Based on this information, we introduce the following notations:

x_i - We denote the grades corresponding to the experimental class by x;

y_i - We denote the grades corresponding to the control class by y;

$\overline{x}$ and $\overline{y}$ - The quantities m and n represent the arithmetic mean values for the experimental and control classes, respectively.

Then, we have:

$$\overline{x} = \frac{\sum x_i n_i}{n}, \quad \overline{y} = \frac{\sum y_i m_i}{m} \quad (1)$$

The equations will be relevant.

In the equations, the variables xi and yi take values of 3, 4, and 5 respectively. The quantities m and n refer to the number of students corresponding to those grades.

It should be noted that the average value evaluating the effectiveness of the educational process is the ratio of the average arithmetic grades of the experimental and control classes, so the efficiency coefficient is obtained as follows.

$$\eta = \frac{\overline{x}}{\overline{y}} \quad (2)$$

The average quadratic deviations are represented as:

$$S_x^2 = \frac{1}{n}\sum_i n_i \cdot (x_i - \overline{x})^2$$

$$S_y^2 = \frac{1}{m}\sum_i m_i \cdot (y_i - \overline{y})^2 \quad (3)$$

The standard deviation values are given by:

$$S_x = \sqrt{S_x^2};\ S_y = \sqrt{S_y^2} \quad (4)$$

The indicator for determining average values is represented by:

$$C_x = \frac{S_x}{\sqrt{n} \cdot \overline{x}} \cdot 100\%; \quad C_y = \frac{S_y}{\sqrt{m} \cdot \overline{y}} \cdot 100\% \quad (5)$$

Confidence intervals for unknown average values of the empty set are determined by:

$$a_x \in \left[\overline{x} - \frac{t}{\sqrt{n}} \cdot S_x;\ \overline{x} + \frac{t}{\sqrt{n}} \cdot S_x\right]$$

$$a_y \in \left[\overline{y} - \frac{t}{\sqrt{m}} \cdot S_y;\ \overline{y} + \frac{t}{\sqrt{m}} \cdot S_y\right] \quad (6)$$

Here, the standardized deviation is determined based on confidence probability. For example:

$$R = 0{,}95 \quad t = 1{,}96 \cdot$$

We propose the hypothesis of equality of average values and test against the alternative hypothesis based on the information above using the student criterion.

$$H_0 : a_x = a_y$$

$$H_0 : a_x \neq a_y$$

$$T_{m,n} = \frac{|\,\overline{y} - \overline{x}\,|}{\sqrt{\frac{S_x^2}{n} + \frac{S_y^2}{m}}} \quad (7)$$

If $T > T_r = t$ the computed value is greater than the critical value, H_1 the hypothesis is rejected, and H_1 the alternative hypothesis is accepted. Below, based on this information, calculations and comparative analyses for each stage will be presented in a table format.

During this scientific research, the initial state of the students' experimental-test results and the end of the experiment were assessed through written and oral evaluations of all topics in the field of Mathematics, as well as the levels of knowledge, skills, and competencies acquired by students in independent work.

Comparative analysis of the conducted experimental test:

$m = 28$ $n = 19$ - The number of students in the experimental and control classes.

a - At the beginning of the experiment.

o - At the end of the experiment.

$$x_a = \frac{1}{28}(6*5+10*4+12*3) = \frac{1}{28}(30+40+36) = \frac{106}{28} = 3{,}79$$

$$y_a = \frac{1}{19}(4*5+6*4+9*3) = \frac{1}{19}(20+24+27) = \frac{71}{19} = 3{,}74$$

Efficiency coefficient:

$$n_a = \frac{x_a}{y_a} = \frac{3{,}79}{3{,}74} = 1{,}01$$

Standard deviation values are given by the following equations:

$$S_x^2 = \frac{1}{28}(6*(5-3{,}79)^2+10*(4-3{,}79)^2+12*(3-3{,}79)^2 =$$

$$= \frac{1}{28}(6*1{,}4641+10*0{,}0441+12*0{,}6241) = \frac{16{,}7148}{28} = 0{,}60$$

$$S_x = \sqrt{S_x^2} = \sqrt{0{,}60} = 0{,}77$$

$$S_y^2 = \frac{1}{19}(4*(5-3{,}74)^2+6*(4-3{,}74)^2+9*(3-3{,}74)^2 =$$

$$= \frac{1}{19}(4*1{,}5876+6*0{,}0676+9*0{,}5476) = \frac{11{,}6844}{19} = 0{,}61$$

$$S_y = \sqrt{S_y^2} = \sqrt{0{,}61} = 0{,}78$$

Average value determination indicators:

$$N_x = \frac{S_x}{\sqrt{28}*3{,}79}*100\% = \frac{0{,}77}{20{,}05}*100\% = 3{,}84$$

$$N_y = \frac{S_y}{\sqrt{19}*3{,}74}*100\% = \frac{0{,}78}{16{,}30}*100\% = 4{,}79$$

$$a_x \in \left[\!\left[3{,}79 - \frac{1{,}96}{\sqrt{28}}*0{,}77; 3{,}79 + \frac{1{,}96}{\sqrt{28}}*0{,}77\right]\!\right] = [\![2{,}6; 3{,}25]\!]$$

$$a_y \in \left[\!\left[3{,}74 - \frac{1{,}96}{\sqrt{19}}*0{,}78; 3{,}74 + \frac{1{,}96}{\sqrt{19}}*0{,}78\right]\!\right] = [\![2{,}6; 3{,}3]\!]$$

Now, let us calculate the results obtained at the end of the experiment:

$$x_o = \frac{1}{28}(15*5+12*4+1*3) = \frac{1}{28}(75+48+3) = \frac{126}{28} = 4{,}5$$

$$y_o = \frac{1}{19}(8*5+8*4+3*3) = \frac{1}{19}(40+32+9) = \frac{81}{19} = 4{,}26$$

Relative growth:

Thus, at the end of the experiment, the experimental group had a performance indicator 1.056 times higher compared to the control group. If we compare it to the beginning of the experiment:

In the experimental class:

$$n_x = \frac{x_o}{x_a} = \frac{4{,}5}{3{,}79} = 1{,}19$$

In the control class:

Significant achievement in effectiveness.

$$n_y = \frac{y_o}{y_a} = \frac{4,26}{3,74} = 1,14$$

For the standard deviation values, the following equations are relevant:

$$S_{x'}^2 = \frac{1}{28}(15 * (5 - 4,5)^2 + 12 * (4 - 4,5)^2 + 1 * (3 - 4,5)^2 =$$

$$= \frac{1}{28}(15 * 0,25 + 12 * 0,25 + 1 * 2,25) = \frac{9}{28} = 0,32$$

$$S_x = \sqrt{S_x^2} = \sqrt{0,32} = 0,57$$

$$S_{y'}^2 = \frac{1}{19}(8 * (5 - 4,26)^2 + 8 * (4 - 4,26)^2 + 3 * (3 - 4,26)^2 =$$

$$= \frac{1}{19}(8 * 0,5476 + 8 * 0,676 + 3 * 1,5876) = \frac{14,5516}{19} = 0,77$$

$$S_y = \sqrt{S_y^2} = \sqrt{0,77} = 0,88$$

Average value determination indicators:

$$N_{x'} = \frac{S_x}{\sqrt{28} * 4,5} * 100\% = \frac{0,57}{23,81} * 100\% = 2,40$$

$$N_{y'} = \frac{S_y}{\sqrt{19} * 4,26} * 100\% = \frac{0,77}{18,57} * 100\% = 4,15$$

$$a_{x'} \in \left[\!\left[4,5 - \frac{1,96}{\sqrt{28}} * 0,57; 4,5 + \frac{1,96}{\sqrt{28}} * 0,57\right]\!\right] = [\![2,4; 2,8]\!]$$

$$a_{y'} \in \left[\!\left[4,26 - \frac{1,96}{\sqrt{19}} * 0,77; 4,26 + \frac{1,96}{\sqrt{19}} * 0,77\right]\!\right] = [\![2,93; 3,62]\!]$$

The results obtained for each stage were analyzed using mathematical-statistical analysis, and based on these results, conclusions were drawn using the Student criterion.

$$T = \frac{|\,\overline{x}_a - \overline{x}_o\,|}{\sqrt{\frac{S_{x_a}^2}{n} + \frac{S_{x_o}^2}{m}}}$$

In the experimental class:

$$x_a = 3{,}79 \text{ va } x_o = 4{,}5$$

- Efficiency coefficient: 3.79 and 4.5

$$n_x = 1.19 \text{ efficiency Indicator .}$$

$$T_x = \frac{|3,79 - 4,5|}{\sqrt{\frac{0,60}{19} + \frac{0,32}{28}}} = \frac{0,71}{0,052} = 13,7.$$

$$T_x = 13,7 > T_{0,95} = 1,96$$

Thus, the hypothesis was not accepted.

In the control class:

- Efficiency coefficient: 3.74

Thus, the hypothesis was not accepted.

The effectiveness indicators of the students' knowledge based on the non-standard lessons in the Mathematics subject are presented in the following table.

№	| Indicators	Educational school	Experimental Class		Control Class	
			At the beginning of the experiment.	At the end of the experiment.	At the beginning of the experiment.	At the end of the experiment.
1	Mean Arithmetic Value	Olot District, 12th school	3,79	4,5	3,74	4,26
2	Efficiency Indicator	Olot District, 12th school	1,19		1,14	
3	Confidence Interval for Average Value ($a_x \in, a_y \in$)	Olot District, 12th school	⟦2,6; 3,25⟧	⟦2,4; 2,8⟧	⟦2,6; 3,3⟧	⟦2,93; 3,62⟧
4	Standard Error of Mean (S_x, S_y)	Olot District, 12th school	0,77	0,57	0,78	0,88
5	Determination Indicator (S_x, S_y)	Olot District, 12th school	3,84%	2,4%	4,79%	4,15%
6	Pupils Criterion	Olot District, 12th school	13,7		7,05	
7	Result Indicators	Olot District, 12th school	H_0 Hypothesis not accepted		H_0 Hypothesis not accepted	

Based on the results in the table, it has been determined that the methodology used in the experimental group is effective compared to the control class. The outcomes of the conducted experiments showed that the indicators of students' skills and competencies in the Mathematics subject were achieved to 1.19 times in the experimental group and 1.14 times in the control group.

Based on the scientific findings, the technological approach of students towards the lesson process and the comparative analysis of their knowledge, skills, and competencies are presented in the following histograms.

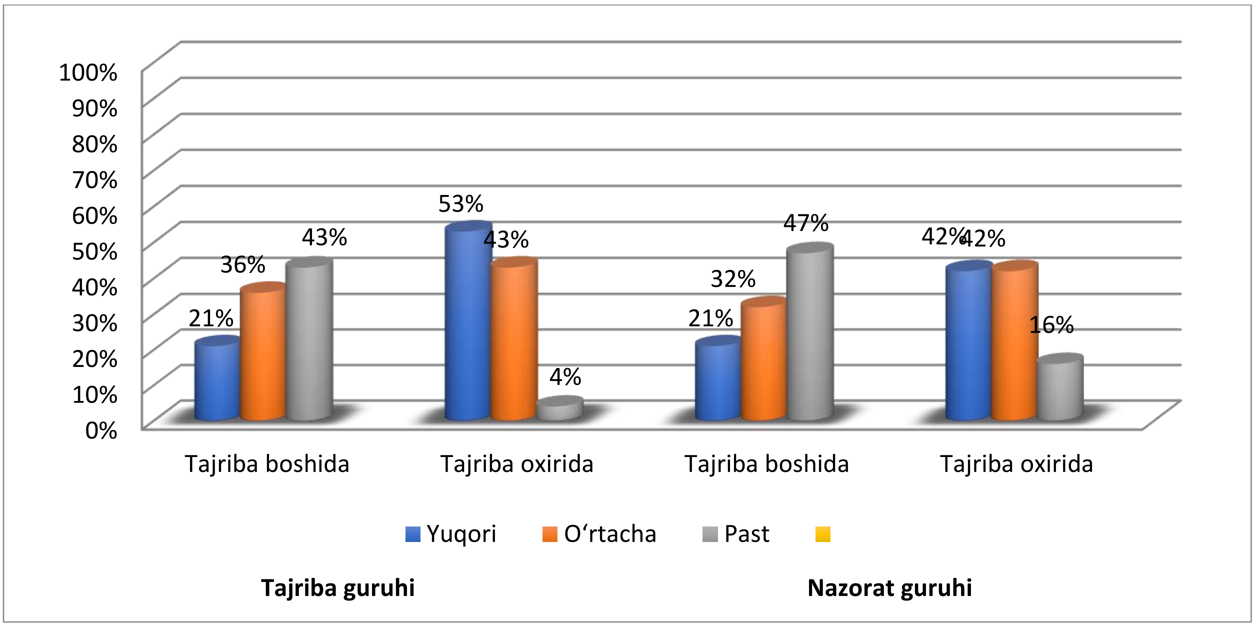

Figure 8: Diagram of Experimental-Test Results

The article was written based on the 9th-grade textbook. Today, in developing countries, there are large methodological foundations supporting modern pedagogical technologies that guarantee the effectiveness of the education process. By using modern teaching methods, it becomes much easier for pupils to understand the topic, and they can also explain the topic to other students.

In conclusion, using the information provided in this article during the teaching process of the topic "Even and Odd Functions" in the Mathematics curriculum enables effective organization of the lesson components, such as reviewing previously taught topics, explaining new topics, and reinforcing the knowledge gained on the subject. In general, using various interactive methods in teaching can make lessons more effective, result-oriented, and interesting. Also, this work contains very necessary information. Interesting Olympiad problems are provided as examples. The goal is to teach students to work independently, not just limit themselves to the examples in the textbook, but also to solve complex Olympiad problems. This helps students develop critical thinking and discover new methods of problem-solving. This is currently a necessity of the time[7-20].

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