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EVALUATION OF THE EFFECTIVENESS OF PHYSICS TEACHING BASED ON THE FLIPPED CLASSROOM MODEL

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Annotatsiya.

Jahonda aniq va tabiiy fanlarni o'qitishda k o'plab metodlar keng tarqalgan, xususan 4K, 5E, Key study, Aqliy hujum, Klaster, Insert, Bumerang hamda Flipped classroom metodi keng foydalaniladi. Biroq, Flipped Classroom metodi boshqa metodlardan birqancha ustunlikka ega bo'lib maktab o'quvchilarini bilimlarini to'la baxolash imkoniyatiga ega. Ushbu tadqiqot ishida Flipped Classroom modeli asosida fizika fanini o'qitish samaradorligi tahlil qilinadi. Tadqiqotning asosiy maqsadi o'quvchilarning o'zlashtirish darajasi, mustaqil fikrlash ko'nikmalari hamda darsga bo'lgan qiziqish va intilishiga mazkur pedagogik yondashuvning ta'sirini aniqlashdan iborat. Tadqiqot jarayonida tajriba va nazorat guruhlari tashkil etilib, an'anaviy o'qitish usuli bilan Flipped Classroom modeli taqqoslandi. Natijalar shuni ko'rsatdiki, Flipped Classroom modeli asosida ta'lim olgan o'quvchilar fizika fanini chuqurroq o'zlashtirgan, muammoli vaziyatlarni hal qilishda faolroq ishtirok etgan hamda o'quv jarayoniga nisbatan yuqori qiziqish bildirgan.

Kalit so'zlar:

Flipped Classroom, fizika ta'limi, innovatsion metodlar, o'qitish samaradorligi, talabalar faolligi, o'zlashtirish darajasi, mexanik energiya, kinetik energiya, potensial energiya, eksperimental tadqiqot.

Аннотация.

В мировой практике преподавания точных и естественных наук широко применяются различные педагогические методы, в частности 4K, 5E, Key Study, мозговой штурм, кластер, INSERT, «Бумеранг», а также метод Flipped Classroom. Однако метод Flipped Classroom обладает рядом преимуществ по сравнению с другими методами и позволяет всесторонне оценивать знания учащихся. В данном исследовании анализируется эффективность преподавания физики на основе модели Flipped Classroom. Основной целью исследования является определение влияния данного педагогического подхода на уровень усвоения знаний учащимися, их навыки самостоятельного мышления, а также интерес и мотивацию к учебному процессу. В ходе исследования были сформированы экспериментальная и контрольная группы, и проведено сравнение традиционного метода обучения с моделью Flipped Classroom. Полученные результаты показали, что учащиеся, обучавшиеся по модели Flipped Classroom, глубже усваивают учебный материал по физике, более активно участвуют в решении проблемных задач и проявляют более высокий интерес к учебному процессу.

Ключевые слова:

Flipped Classroom, физическое образование, инновационные методы, эффективность обучения, активность учащихся, уровень усвоения, механическая энергия, кинетическая энергия, потенциальная энергия, экспериментальное исследование.

Abstract.

In global practice, numerous methods are widely used in teaching exact and natural sciences, including 4K, 5E, Key Study, brainstorming, clustering, INSERT, Boomerang, and the Flipped Classroom method. However, the Flipped Classroom method has several advantages over other approaches and enables a comprehensive assessment of students' knowledge. This study analyzes the effectiveness of teaching physics based on the Flipped Classroom model. The main objective of the research is to determine the impact of this pedagogical approach on students' level of understanding, independent thinking skills, as well as their interest and motivation toward learning. During the research, experimental and control groups were formed, and the traditional teaching method was compared with the Flipped Classroom model. The results showed that students taught using the Flipped Classroom model demonstrated deeper understanding of physics, were more active in solving problem-based tasks, and showed greater interest in the learning process.

Keywords:

Flipped Classroom, physics education, innovative methods, teaching effectiveness, student activity, level of achievement, mechanical energy, kinetic energy, potential energy, experimental research.

In the modern education system, the issue of organizing the learning process based on innovative approaches is becoming increasingly relevant. In particular, in teaching physics, one of the key tasks is to develop students' ability to deeply understand theoretical knowledge, apply it in practical situations, and develop independent thinking skills [1]. However, practice shows that traditional teaching methods do not sufficiently ensure students' active

participation in the learning process; as a result, complex physical concepts are only superficially understood, and difficulties arise when applying them to real problem-solving situations. In order to eliminate these shortcomings, the 4K and 5E models have been applied [2]. The following results were obtained from these models.

Tony Wagner, an expert at the Harvard University Innovation Lab, developed the 4K model, which consists of four essential skills that every student and professional must possess to succeed in the 21st century. This system was implemented as part of global efforts to reform school education. According to Tony Wagner, for the effectiveness of the 4K model, the number of students in a class should be around 18–20, and the lesson duration should be 45 minutes. This allows for individual interaction with each student. To develop 4K competencies, activities such as opinion corners, classroom mixing, collaborative problem-solving, project-based learning, and engaging skits were used during lessons. Through these activities, students selected ideas aligned with their own views, expressed themselves freely during discussions, learned from their classmates' perspectives, developed critical thinking and teamwork skills, and learned to generate creative solutions collaboratively as well as present their ideas visually. Tony Wagner emphasized that the 4K model transforms education from a process of simply delivering information into a process of shaping the individual. This model turns students from passive listeners into active creators. The 4K skills are considered the “four pillars” of the modern world, enabling students to navigate any situation effectively[3].

The 5E model was developed in 1987 under the leadership of American educator Roger Bybee as part of the BSCS (Biological Sciences Curriculum Study) project. The main goal of this project was to ensure that students do not merely receive information, but instead construct knowledge based on their own experiences. During his research, Roger Bybee stated that the optimal class size is 15–20 students with a lesson duration of 45 minutes. The learning process was divided into five logical stages (Engage, Explore, Explain, Elaborate, Evaluate), creating a structured methodological guide for teachers. During lessons, activities such as mystery boxes, laboratory investigations, group discussions, and knowledge transfer exercises were used. Through these activities, students developed curiosity by asking questions, learned to find answers through observation, explained results based on their own experiments, and completed assignments based on imagined principles[4]. Research has shown that students taught using the 5E model achieved test results 20–30% higher than those taught using traditional methods. Because knowledge is acquired through practical experience, students' retention improved significantly, their participation and interest in the subject increased, and they learned to analyze information rather than simply receive it[4].

However, these models require appropriate conditions, and class size must be strictly regulated. In particular, if necessary conditions are not met, these models do not produce the desired effectiveness. Therefore, it becomes necessary to use the Flipped Classroom method for school students[5].

The development of digital technologies and the shift of educational resources to online formats have created broad opportunities for reorganizing the teaching process. One such innovative approach is the Flipped Classroom model, which allows students to independently study theoretical materials outside the classroom, while lesson time is dedicated to interactive activities, problem-solving tasks, and practical exercises. This model is significant because it increases students' engagement in the learning process, develops critical thinking, and promotes deeper understanding of knowledge. However, the systematic and empirical

evaluation of its effectiveness in physics teaching, especially in local educational contexts, remains insufficiently studied[6].

One of the main problems in physics education is students' difficulty in understanding abstract concepts and their low ability to apply them in practice. In traditional lessons, the teacher plays a central role, which limits students' opportunities for independent learning and active participation. As a result, students' interest in learning decreases, and the durability of knowledge is not sufficiently ensured.

From this perspective, the research problem is defined by the need to identify the effectiveness of the Flipped Classroom model in physics education, particularly its impact on students' knowledge level, depth of conceptual understanding, and learning engagement, and to evaluate it on a scientific basis. This study aims to determine the impact of this model on the educational process, reveal its advantages and limitations, and develop scientific and practical recommendations for improving the quality of physics education[7]. In this regard, the need to introduce modern pedagogical technologies into the educational process determines the relevance of the topic.

In the modern school education system, interactive teaching methods are increasingly being used in physics lessons to ensure deeper understanding of the subject by students. Flipped Classroom is a teaching strategy and a form of blended learning. It aims to increase students' engagement and learning by having them complete learning activities at home and work on real problems during class time. This pedagogical approach brings activities traditionally considered homework into the classroom. In the Flipped Classroom model, students watch online lectures, participate in online discussions, or conduct research outside the classroom, while class time is used to actively engage with concepts under the guidance of the teacher[8].

In traditional classroom lessons, the teacher is usually the central figure and the main source of information during the lesson. The teacher answers questions, and students directly turn to the teacher for guidance and feedback. Many traditional teaching models rely on lecture-based presentations of individual lessons, limiting student participation to activities where they work independently or in small groups on practical tasks designed by the teacher. The teacher typically plays a central role in classroom discussions, guiding the flow of conversation. Usually, this teaching style also includes assigning students tasks such as reading textbooks at home or practicing concepts by working on problem sets[9].

Lesson topic:

Types of Mechanical Energy. Kinetic and Potential Energy.

Lesson type:

Interactive lesson organized based on Flipped Classroom technology

Lesson objectives:

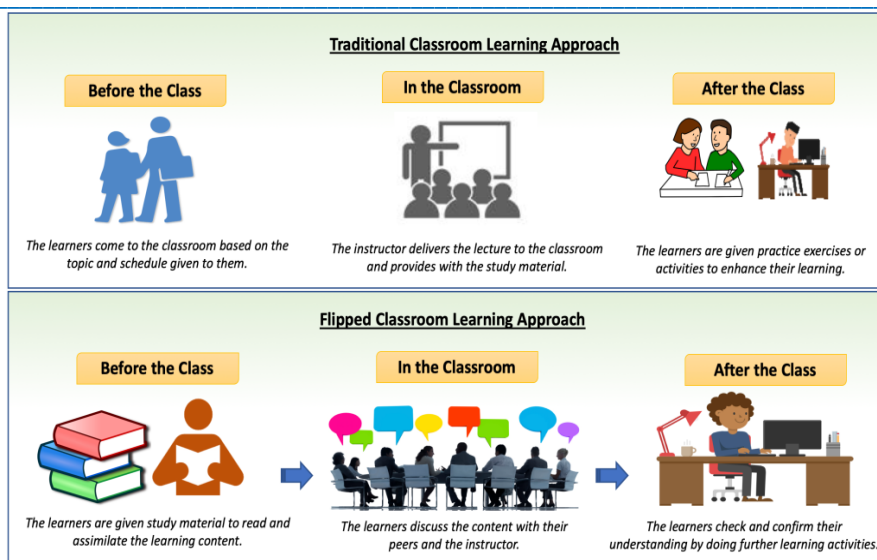
To provide an understanding of the types of mechanical energy (kinetic and potential energy);

To teach the physical meaning of kinetic and potential energy and their formulas;

To develop the ability to analyze physical phenomena through real-life examples.

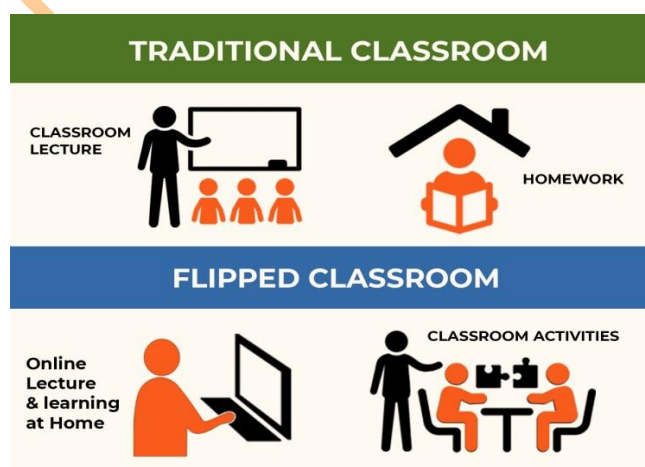
Teaching methods:

Flipped Classroom, Case Study, brainstorming, problem-based learning, group work, tests, presentations, and the KWL chart



What is the Flipped Classroom approach?

The Flipped Classroom method is the opposite of the traditional classroom learning model, where students are taught lectures in class and are given assignments or exercises as homework. In the Flipped Classroom approach, students are provided with learning materials to study at home. Then, students come to class to discuss the learning content with their peers and the teacher in order to gain a deeper understanding. Therefore, in the Flipped Classroom model, classroom time is used for discussing the topic and engaging in more learning activities that help students develop a deeper understanding of the subject. After class, students further deepen their learning through online discussions, experiments, or real-life applications. This teaching strategy uses a blended learning approach, combining both digital tools and traditional face-to-face teacher-led instruction. Before class, students are provided with online educational content such as lectures and videos. In class, students discuss their learning with peers, complete more learning activities, ask questions to the teacher, and receive feedback [10].



Lesson progress:

I. Organizational stage

At the beginning of the lesson, the teacher greets the students, checks attendance, and creates a positive psychological atmosphere in the classroom. Since students come to the lesson well-prepared based on the Flipped Classroom model, their prior knowledge gained at home is briefly assessed through a short question-and-answer session or a mini test. After that, the teacher creates a problem situation to attract students' attention to the lesson. Questions based on real-life examples stimulate students' interest and encourage active thinking. The lesson objectives are defined jointly by the teacher and students, which increases students' engagement in the learning process.

II. Activating previously learned (home-studied) material stage

At this stage, the teacher checks students' knowledge based on the video or learning materials they studied at home.

Questions:

What is mechanical energy?

How are types of energy classified?

Give examples of mechanical energy in everyday life.

Based on students' answers, a short discussion is organized. In addition, a mini-test or quick quiz is used to determine their level of understanding.

In the Flipped Classroom model, this stage is focused on activating students' prior knowledge and analyzing it through problem situations. The "Physics Detective" method is applied here.

The teacher presents the following "mysterious situation" to the class:

"When an object is lifted upward, its velocity decreases, but where does the lost energy go?"

Students are divided into "detective groups," and each group is assigned a task:

Group 1: Analyze the energy of a moving object (kinetic energy)

Group 2: Analyze the energy of an object at height (potential energy)

Group 3: Explain the reasons for energy transformation

Each group formulates its conclusion based on "evidence cards" (videos, formulas, or examples studied at home).

Then the teacher asks the final question:

"Is energy lost or has it changed its form?"

Students defend their conclusions, and a short classroom discussion (mini-debate) is organized.

As a result, students reactivate their home-learned knowledge through a practical problem and gain a deeper understanding of kinetic and potential energy.

Group work table for the Physics Detective method (English version):

Groups	Analytical task (detective task)	Knowledge used (evidence)	Expected conclusion
Group 1 (Kinetic Detectives)	Why does a moving object (for example, a ball or a cart) have	Kinetic energy formula: $E_k = \frac{mv^2}{2}$	A moving object has kinetic energy, and it

Groups	Analytical task (detective task)	Knowledge used (evidence)	Expected conclusion
	energy? What happens if its velocity changes?		depends on its velocity.
Group 2 (Potential Detectives)	What kind of energy does an object have when it is raised to a height? Why does it accelerate when it falls down?	Potential energy formula: $E_p = mgh$	An object at a height has potential energy.
Group 3 (Energy Mystery Solvers)	Where does energy go: is it lost or does it transform?	Law of conservation of energy; the relationship between kinetic and potential energy	Energy is not lost; it only transforms from one form to another

Main part: Mechanical energy is a type of energy associated with the motion of objects or their position relative to each other. It has two main forms: kinetic energy and potential energy. Mechanical energy plays an important role in explaining many natural processes and is studied based on the law of conservation of energy.

Kinetic energy is the energy associated with the motion of an object. Any moving object possesses kinetic energy. As the mass and velocity of an object increase, its kinetic energy also increases. Kinetic energy is calculated using the following formula.

$$E_k = \frac{mv^2}{2} \quad (1)$$

where m is the mass of the object (kg) and v is its velocity (m/s). From this formula, it can be seen that if the velocity doubles, the kinetic energy increases four times. For example, a moving car or a flying ball has kinetic energy.

Potential energy is the energy associated with the position or state of an object. The most common type is gravitational potential energy, which depends on the object's height above the Earth's surface. Potential energy is expressed by the following formula.

$$E_p = mgh \quad (2)$$

where m is mass (kg), g is the acceleration due to gravity ($\approx 9.8 \text{ m/s}^2$), and h is height (m). The higher an object is located, the greater its potential energy. For example, a stone at a height or water stored in a reservoir has potential energy.


In addition, there is also elastic potential energy, which is stored in deformed objects such as compressed or stretched springs.

An important feature of mechanical energy is that it can transform from one form into another. For example, when an object falls from a height, its potential energy decreases while

its kinetic energy increases. If no external forces act on the system, the total mechanical energy remains constant:

$$E_m = E_p + E_k \quad (3)$$

This is known as the law of conservation of energy.

- 
- If no external forces (such as friction or air resistance) act on the system, the total mechanical energy of the object remains constant; that is, the sum of kinetic and potential energies stays unchanged.

Mechanical energy is widely used in everyday life: in hydroelectric power stations, the potential energy of water is converted into kinetic energy and then into electrical energy; in transportation, kinetic energy plays an important role in motion; and in various mechanical devices, the transformation of energy from one form to another can be observed.

Thus, kinetic and potential energy are the main types of mechanical energy. They depend on the motion and position of objects and help explain many phenomena in nature.



III. Consolidation of the new topic:

The new topic is reinforced using a Venn diagram.

Divide the class into small groups and give them the following task:

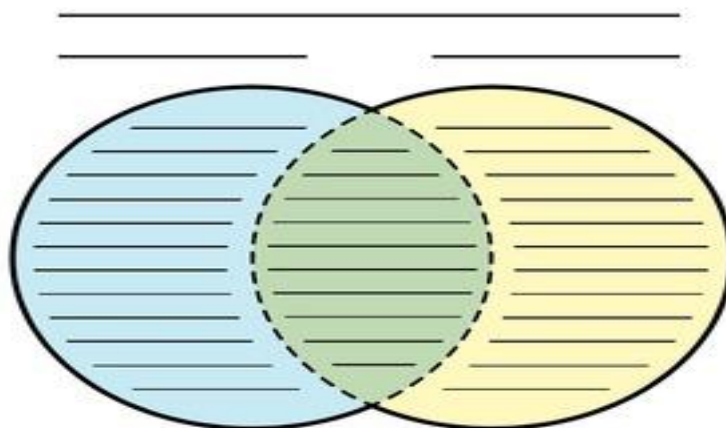
Kinetic energy and Potential energy

Students should:

Identify differences (motion-dependent / position-dependent)

Identify similarities (both are types of energy, measured in joules (J))

This method helps learners study concepts through comparison.



Name _____

Date _____

IV. Lesson conclusion:

At the end of the lesson, the “Conclusion Chain” method is used. The following questions are written on the board:

What is mechanical energy?

What is kinetic energy?

What is potential energy?

Students answer in sequence and draw a general conclusion:

Mechanical energy is the sum of kinetic and potential energy

Kinetic energy depends on motion

Potential energy depends on position (height)

This method helps to summarize the topic briefly and clearly.



Mechanical energy



Kinetic energy



Potential energy

At the end of the lesson, the main concepts are summarized and students are assessed. Assessment criteria include: correct use of formulas, correct conversion of units, ability to explain cause-and-effect relationships, and active participation in group work.

V. Homework.

Students are assigned to read the topic, study the concepts of mechanical energy, kinetic and potential energy, write and memorize the formulas for kinetic energy ($E_k = mv^2/2$) and potential energy ($E_p = mgh$), and provide one example from everyday life explaining the type of energy involved.

The research was conducted using a quasi-experimental design. It involved students from grades 7-“A” and 7-“B” of School No. 50 in Andijan city, Andijan region. The classes were selected from existing parallel groups. In the study, 7-“A” served as the control group and was taught using traditional teaching methods, while 7-“B” served as the experimental group and participated in interactive lessons based on the Flipped Classroom approach. Before the experiment began, students’ initial knowledge levels were assessed using a diagnostic test. The results showed that the overall knowledge levels of both groups were sufficiently comparable for further analysis.

At the end of the study, a final test was conducted and the results were compared. The number of students participating in the experiment is shown in Table 1.

Table 1. Number of students participating in the experiment

No	Educational institution	Control group	Number of students	Experimental group	Number of students
1	50 st General Secondary School	7-“A”	21	7-“B”	22

Before the study, the learning achievement levels of students in the control group were determined based on the results of the diagnostic test. The results are presented in Table 2

Table 2. Learning achievement levels of students in the control group before the study

No	Class	Number of students	Knowledge levels			
			0-55%	56-70%	71-85%	86-100%
			Grade 2	Grade 3	Grade 4	Grade 5
1	7“A”	21	5	5	7	4

Before the study, the learning achievement levels of students in the experimental group were determined based on the results of the diagnostic test. The results are presented in Table 3.

Table 3. Learning achievement levels of students in the experimental group before the study

No	Class	Number of students	Knowledge levels			
			0-55%	56-70%	71-85%	86-100%
			Grade 2	Grade 3	Grade 4	Grade 5
1	7“B”	22	6	8	4	4

The table results show that at the beginning of the study, knowledge levels of students in both groups were almost the same, with no significant differences observed. This allow for a

reliable comparison of the results after the experiment. The level of mastery was calculated as follows:

$$\eta = \frac{M}{N} \cdot 100\% \quad (4)$$

Where: η - level of mastery (%), N - total number of students, M - sum of students who received grades 4 and 5.

Calculations:

7- "A" class (Control group)

Grade 4: 7 students

Grade 5: 4 students

Total students: 21

Initial result:

$$M = 7+4 = 11$$

$$\eta_1 = \frac{11}{21} * 100 = 52.4\%$$

Final result:

$$M = 8+5 = 13$$

$$\eta_2 = \frac{13}{21} * 100 = 61.9 \%$$

Control group improvement: $61.9 - 52.4 = 9.5 \%$

7- "B" class (Experimental group)

Grade 4: 4 students

Grade 5: 4ta students

Total students: 22

Initial result:

$$M = 4+4 = 8$$

$$\eta_1 = \frac{8}{22} * 100 = 36.4 \%$$

Final result:

$$M = 7+5 = 12$$

$$\eta_2 = \frac{12}{22} * 100 = 54.5 \%$$

Experimental group improvement: $54.5 - 36.4 = 18.1 \%$

Difference in improvement between groups:

$$\Delta\eta_{\text{total}} = 18.1 \% - 9.5 \% = 8.6 \%$$

According to the analysis, the proportion of students achieving high grades (4 and 5) in the experimental class increased from 36.4% to 54.5%, representing an improvement of 18.1 percentage points. In the control class, this indicator increased from 52.4% to 61.9%, representing an improvement of 9.5 percentage points. Thus, the experimental class demonstrated an 8.6 percentage-point greater improvement than the control class. To improve the methodological system for developing students' competencies in physics, a quasi-experimental study was conducted at the 50 st General Secondary School. During the study, tests were administered to evaluate the effectiveness of the educational content, the selected

teaching methodology, and the instructional tools used in the learning process. The test consisted of 15 questions and had a total duration of 45 minutes, allowing approximately 3 minutes per question. Each question included four answer options (a, b, c, d), with only one correct answer. Each correct response was awarded 1 point, and the maximum possible score was 15 points. The obtained results were then analyzed.

Grading criteria based on the scores were as follows:

13–15 points – Grade “5” (excellent)

10–12 points – Grade “4” (good)

7–9 points – Grade “3” (satisfactory)

0–6 points – Grade “2” (unsatisfactory)

Based on the results of the experimental study, the findings are presented in Tables 4 and 5.

Table 4. Learning achievement levels of control class students at the end of the study

№	Class	Number of students	Knowledge levels			
			0-55%	56-70%	71-85%	86-100%
			Grade 2	Grade 3	Grade 4	Grade 5
1	7-“A”	21	4	4	8	5

Table 5. Learning achievement levels of experimental class students at the end of the study

№	Class	Number of students	Knowledge levels			
			0-55%	56-70%	71-85%	86-100%
			Grade 2	Grade 3	Grade 4	Grade 5
1	7-“B”	22	4	6	7	5

According to the final results, the proportion of students achieving high grades (4 and 5) in the experimental class increased significantly. In particular, it was observed that students with average performance improved their knowledge levels. This confirms the effectiveness of the Case study method.

Table 6. Comparative analysis of the level of Methodological System Improvement in developing students' competencies in Physics

Classes	Number of students	Knowledge levels			
		2 point	3 point	4 point	5 point
Control class	21	5	5	7	4
		4	4	8	5
Experimental class	22	6	8	4	4
		4	6	7	5

Figure 1

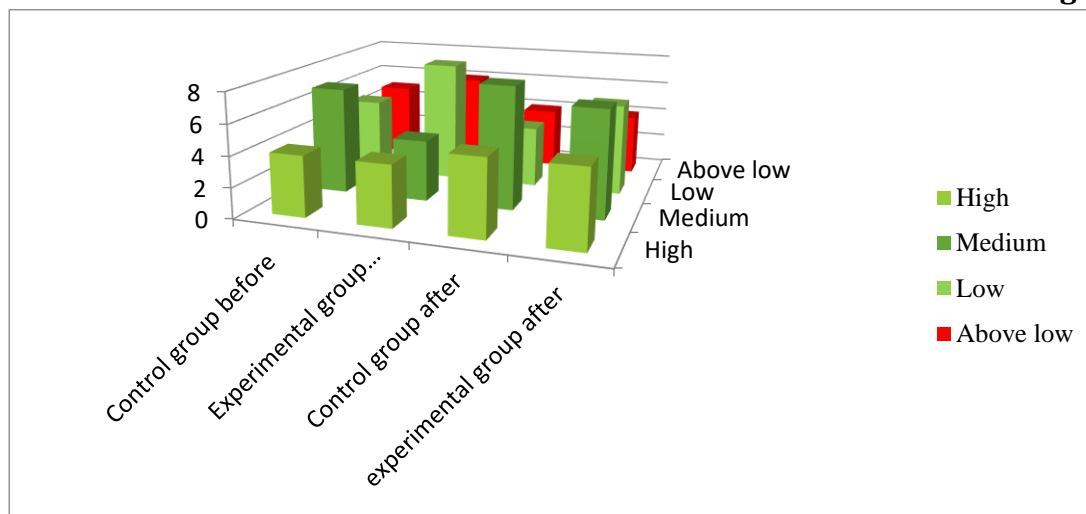


Figure 1. Comparative diagram of the level of Methodological System Improvement in developing students' competencies in physics

According to the obtained results, the findings of the conducted pedagogical research confirmed that the selected model for teaching physics based on an innovative approach, the educational content, the chosen teaching methodology, as well as the lessons developed on this basis and the organizational forms and tools used in their implementation, are appropriate and effective. The research results indicate that students in the experimental group demonstrated significantly higher levels of theoretical knowledge, practical skills, and competencies compared to students in the control group. According to the experimental results, it was determined that students' overall achievement increased by an average of 8.6%. This achievement was calculated based on the difference between the initial and final results.

Conclusion. In this article, the effectiveness of using the Flipped Classroom model in teaching the topic "Types of Mechanical Energy" was investigated. The results of the study showed that this approach has a positive impact compared to traditional teaching methods, leading to a deeper understanding of the topic by students, strengthening theoretical knowledge, and improving problem-solving skills.

In lessons organized based on the Flipped Classroom model, students had the opportunity to independently study theoretical materials in advance, while classroom activities focused mainly on discussion, analysis, and completing practical tasks. This approach increased students' engagement in the learning process and contributed to the development of their independent thinking, analytical skills, and problem-solving abilities.

A comparison of the experimental and control group results showed a significant improvement in the experimental group. In particular, the proportion of students achieving high performance in the experimental group increased from 35.2% to 56.8%, an increase of 21.6 percentage points, while in the control group this indicator increased from 50.4% to 60.1%, representing a 9.7 percentage-point increase. As a result, the improvement in the experimental group was 11.9 percentage points higher

than in the control group. In conclusion, the Flipped Classroom model is an effective pedagogical approach for teaching physics, particularly the topic “Types of Mechanical Energy.” It not only improves students’ academic achievement but also develops their independent learning, analytical thinking, and practical skills. Therefore, it is advisable to widely implement this model in general secondary schools. The obtained results can serve as a methodological basis for improving the quality of physics education and enhancing students’ interest in the subject as well as their competencies.

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