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The Role of Metacognitive Strategies in Increasing the Efficiency of Physics Teaching

Rakhmanov Valijon Turdaliyevich

Gulistan State University, Faculty of Information Technologies and Physics and Mathematics, Associate Professor of the Department of Physics, Doctor of Philosophy in Pedagogical Sciences (PhD), Gulistan city, Uzbekistan

Topiboldiev Jonibek Akhmadjon o‘g‘li

Gulistan State University, Faculty of Information Technologies and Physics and Mathematics, 1st year master's students in the "Physics" major. Gulistan city, Uzbekistan

Mahmudjon Rakhmatullayev Mirzayevich

Gulistan State University, Faculty of Information Technologies and Physics and Mathematics, 1st year master's students in the "Physics" major. Gulistan city, Uzbekistan

Ortiqboyev Sunnatillo Mamadali o‘g‘li

Gulistan State University, Faculty of Information Technologies and Physics and Mathematics, 1st year master's students in the "Physics" major. Gulistan city, Uzbekistan

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ABSTRACT

This article highlights the pedagogical and methodological importance of metacognitive strategies in improving the effectiveness of physics teaching. The main goal of the study is to increase the level of independent thinking and conscious assimilation of knowledge by developing metacognitive skills such as planning, control and evaluation in students. The article, based on an analysis of domestic and foreign scientific sources, reveals the theoretical foundations of the concept of metacognition and justifies its role in physics education. It also proposes effective mechanisms for implementing the metacognitive approach in general secondary schools. The study used observation, questionnaire, pedagogical experiment and statistical analysis methods. The results showed that students' interest in science, ability to analyze problem situations and self-assessment skills significantly increased in lessons organized on the basis of metacognitive strategies. The scientific novelty of the article is the development of a model for designing physics lessons based on a metacognitive approach and substantiating the mechanisms for integrating it into the teaching process. The results are of great importance in developing methodological recommendations for physics teachers and introducing innovative approaches aimed at improving the quality of education. The approach proposed in the article forms a culture of reflection in students, helps to understand knowledge more deeply, and allows organizing the teaching process on the basis of subject-subject relationships. This serves to ensure sustainable educational effectiveness. Therefore, metacognitive strategies are considered an important scientific and practical basis for the modernization of physics education, expanding the methodological potential of the teacher and enhancing innovation.

Keywords: Metacognitive strategies, metacognition, physics education, effectiveness of the learning process, independent learning, reflection, self-control, problem-based learning, quality of education, innovative pedagogical approach.

INTRODUCTION

In the current era of globalization and the rapid development of digital technologies, the education system is facing new and complex tasks. Modern society requires individuals who are not only knowledgeable, but also able to think independently, analyze problems, and consciously manage their own learning process. Therefore, in the educational process, it is important not only for the student to acquire ready-made knowledge, but also how to organize the process of acquiring knowledge, what strategies to use, and how to evaluate their own activities. This creates the need to introduce metacognitive approaches into the educational process.

The importance of metacognitive strategies increases, especially in teaching subjects such as physics that require logical thinking, analysis, generalization, and decision-making in problem situations. In physics, students are often forced to work with complex formulas, abstract concepts, and theoretical laws. In the traditional approach, this process is more focused on providing ready-made knowledge, and the student's active participation and independent thinking are not sufficiently provided. As a result, students tend to memorize knowledge mechanically and have difficulty applying it in practical situations.

Metacognitive strategies, on the other hand, enable students to plan, monitor, and evaluate their own learning process. This approach shapes students as active subjects in the learning process. Students become aware of their strengths and weaknesses, understand how to learn more effectively, and choose conscious strategies for solving problems. This approach provides a deeper understanding of physics and develops students' logical and critical thinking skills.

Today, metacognitive approaches are recognized in international educational experience as an important factor in improving the quality of education. International assessment programs such as PISA assess not only students' knowledge, but also how they think in problem situations and how they manage their activities. This indicates the need to develop students' independent learning skills in school education. Metacognitive competencies are considered an integral part of the skills of the 21st century.

The education system of Uzbekistan has also undergone fundamental reforms in recent years. Approaches aimed at updating the content of education, introducing modern pedagogical technologies, and developing independent thinking of students are widely used. The use of innovative methods, digital resources, virtual laboratories, and interactive tools in teaching physics is also expanding. However, in order to effectively use these tools, it is important to form in students the skills to manage their own learning activities, analyze results, and draw conclusions. It is at this point that metacognitive strategies serve as an important methodological basis.

This article discusses the role of metacognitive strategies in increasing the effectiveness of teaching physics from a scientific, theoretical, and practical perspective. The relevance of the topic is that although many studies have studied the impact of metacognitive approaches on overall educational effectiveness, the issue of their systematic introduction in the process of teaching physics has not been studied in sufficient depth. This article differs from existing scientific works in that it is aimed at substantiating methodological mechanisms for integrating metacognitive strategies into physics lessons.

The study analyzes the theoretical foundations of the concept of metacognition, its components - metacognitive knowledge and metacognitive control elements. It also shows ways to achieve conscious assimilation of knowledge by students through the organization of planning, monitoring and reflection processes in physics lessons. Lessons organized on the basis of a metacognitive approach increase the activity of students, encourage them to think independently in problem situations, and expand their opportunities for applying knowledge in practice.

Therefore, the use of metacognitive strategies in physics education not only improves students' academic performance, but also serves to form them as individuals who can solve life problems and consciously manage their activities. This article aims to reveal the scientific foundations of this process and offer methodological directions for physics teachers.

The concept of metacognitive and its historical significance

The term “metacognitive” comes from the concept of “metacognition”, which means that a person thinks about his own thinking process, that is, “knows how he thinks”. Simply put, metacognition is a person’s ability to understand and manage his own knowledge, learning methods, level of understanding and errors. A metacognitive process occurs when a person is not limited only to acquiring knowledge, but also begins to understand how he acquires this knowledge, which method is more effective.

The concept of metacognition in scientific literature was first introduced into scientific circulation in the 70s of the 20th century by the American psychologist J. Flavell. He interpreted metacognition as a person’s knowledge of his own cognitive processes and the ability to manage them. Flavell’s research showed that successful learners not only have more knowledge, but also are more active in planning, monitoring and evaluating their learning process. Thus, metacognition has become an important scientific concept in educational psychology.

The historical significance of the metacognitive approach is that it laid the foundation for the transition of education from the “providing ready-made knowledge” model to the “teaching to learn” model. In previous approaches, the teacher was the main source of knowledge, and the student played the role of a passive receiver. The metacognitive approach sees the student as an active subject of the educational process. This marked a fundamental shift in the philosophy of education and gave rise to the concept of person-centered education.

The importance of metacognition in the educational process is extremely great. Because it teaches the student to consciously manage his knowledge. A student with metacognitive skills:

- sets goals and makes a plan before learning;

- checks his understanding during the learning process;

- identifies and tries to correct his mistakes;

- evaluates the result and draws conclusions for future activities.

Such a student not only memorizes knowledge, but also understands, analyzes and can apply it in new situations. This is especially important when studying complex and logical subjects such as physics. Physical concepts are interconnected, and their deep understanding requires the student to control the thinking process. Through a metacognitive approach, the student learns to ask himself questions such as “what do I know?”, “what did I not understand?”, “how can I solve this problem correctly?”.

Thus, metacognition enriches education in content, forms the student as an independent thinker, and makes the learning process conscious, effective, and sustainable. Its historical and practical significance is that it serves to realize the idea of "teaching to learn," which is the main goal of modern education.

The relevance of the topic and its differences from other scientific works

In modern society, the requirements placed on the education system are becoming increasingly complex. Today, a school graduate is required not only to have knowledge in a particular subject, but also to have such competencies as independent thinking, making the right decisions in problem situations, planning and evaluating his/her activities. Especially in conditions of accelerated scientific and technological progress, the study of physics is considered not only as a set of theoretical knowledge, but also as a means of analyzing and solving life problems. Therefore, the issue of increasing the effectiveness of physics education is one of the current scientific and pedagogical problems today.

Practice shows that many students perceive physics as a complex, difficult and abstract subject. This is often due to the passive participation of the student in the lesson process, the predominance of an approach based on memorizing ready-made formulas and rules. As a result, students tend to mechanically assimilate knowledge instead of consciously comprehending it. In such conditions, it becomes difficult to achieve sustainable educational effectiveness. It is at this point that metacognitive strategies appear as an effective tool that allows you to radically renew the educational process.

The metacognitive approach serves to form the student not as a passive subject of knowledge, but as an active person who manages his own learning process. It teaches the student to consciously ask questions such as “what do I know?”, “what did I not understand?”, “which method is more effective?” This develops in students the skills of reflection, self-control and self-evaluation. Today, in international educational experience, it is precisely such competencies that are recognized as the skills of the 21st century. Therefore, the introduction of metacognitive strategies into physics education is not only a methodological necessity, but also a requirement of the time.

The relevance of the topic is also due to the fact that in the context of the widespread introduction of digital technologies, interactive platforms and virtual laboratories in the education system, the student's ability to manage his own activities is gaining importance. In conditions of an abundance of information, the student needs to be able to understand which information is important and which is secondary, plan the learning process and evaluate the result. Metacognitive strategies serve to effectively organize this process. Therefore, their role in physics education is of particular scientific importance today.

The difference of this study from other scientific works is that it analyzes metacognitive strategies not from a general pedagogical point of view, but inextricably linked to the specific features of physics. In most existing studies, the concept of metacognition is covered in relation to the general educational process, and its methodological mechanisms in specific subjects, in particular physics lessons, are not sufficiently systematized. In this work, the issue of harmonizing the metacognitive approach with the content, structure and methods of physics lessons is put in the center.

In addition, the article proposes a practical model for designing physics lessons based on metacognitive strategies. In this model, all stages of the lesson - motivation, assimilation of new knowledge, consolidation and reflection processes - are considered in connection with metacognitive activity. This approach, unlike existing scientific works, is not limited to theoretical recommendations, but also substantiates methodological mechanisms that allow them to be applied to the real lesson process.

Thus, this topic is of great importance not only theoretically, but also practically, and serves to modernize physics education, positively change students' attitudes towards knowledge, and increase educational effectiveness. By systematically introducing metacognitive strategies into physics education, it becomes possible to form students as conscious, independent, and responsible learners. This fully corresponds to the main goals of modern education.

LITERATURE REVIEW

The issue of metacognitive strategies has been emerging as an important scientific direction in the theory and practice of education in recent years. Research conducted by Uzbek, CIS and foreign scientists in this area scientifically substantiates the need to develop the student's conscious activity in the educational process.

Among the Uzbek scientists, researchers such as Kh. Kh. Khasanov, A. A. Turaev, B. S. Qodirov, M. A. Joraev have covered the issues of organizing the educational process on the basis of a competency-based and person-oriented approach in their works. Kh. Khasanov's research on pedagogical technologies indicates that activating the student's cognitive activity and developing independent thinking are the main conditions for the effectiveness of education. In his works, the elements of reflection and self-assessment are interpreted as important components of the educational process.

A. A. Turaev's research on the methodology of teaching natural sciences covers the development of students' logical thinking and deep assimilation of knowledge through problem situations. He substantiates that the use of problem questions and research-oriented tasks in physics lessons increases student activity. However, in these works, metacognitive activity is considered not as a separate system, but as a general methodological tool.

The work of B. S. Kadyrov and M. A. Juraev also focuses on the development of students' independent learning activities in the educational process. They emphasize the need to form students' skills in analyzing their own activities, evaluating the results, and drawing conclusions. Although these views are consistent with the ideas of the metacognitive approach, the mechanisms for their systematic application in physics education have not been sufficiently developed.

Among the scientists from the CIS countries, L. S. Vygotsky, A. N. Leontev, P. Ya. Researchers such as Galperin, V. V. Davydov created the psychological foundations of cognitive activity. Vygotsky's theory of the "zone of proximal development" shows the importance of conscious assistance and reflection in the learning process of the student. Leontiev, based on the activity approach, interprets the cognitive process as an active, conscious activity. These ideas later served as the theoretical basis for the formation of the metacognitive approach.

Russian researchers such as A. K. Markova, I. A. Zimnyaya, T. V. Kudryavtseva have extensively analyzed the issues of forming students' self-control, reflective thinking, and independent learning skills in their work. They substantiate the need to teach students to control their thinking processes in order to consciously assimilate knowledge. However, in the CIS literature, the concept of metacognition is often expressed indirectly, through terms such as "reflection", "self-control", and their adaptation to the specific structure of physics lessons is not sufficiently systematized.

In foreign scientific literature, the issue of metacognition has been formed as an independent and complete scientific direction. American psychologist J. Flavell introduced the concept of metacognition into scientific circulation, defining it as a person’s knowledge of his own cognitive processes and the ability to control them. A. Brown explains metacognitive activity as a conscious process carried out through the stages of planning, monitoring and evaluation.

B. Zimmerman and P. Pintrich [pp. 3–17, p. 219–225] in their research developed a model of “self-directed learning” and experimentally proved that metacognitive strategies directly affect students’ academic success. Their work shows that students who achieve high results consciously plan, control and evaluate their learning process.

In foreign studies, in particular, in works devoted to the education of physics and other natural sciences, the effectiveness of the metacognitive approach is emphasized. In the process of solving a problem, the student is required to answer questions such as “why did you choose this path?”, “how did you check the result?”, etc., which deepens his thinking process. As a result, knowledge is acquired not superficially, but consciously and sustainably. The analysis shows that although metacognitive strategies are well developed in foreign literature in theoretical and practical terms, this area has not yet been sufficiently systematized in domestic and CIS literature. This article aims to fill this gap and, summarizing the ideas put forward by Uzbek, CIS and foreign scientists, develops scientific and methodological foundations for the appropriate integration of metacognitive strategies into physics education.

Theoretical foundations of metacognitive strategies

In the modern education system, the issue of developing students' independent thinking, conscious assimilation of knowledge, and effective organization of the learning process is gaining urgent importance. Especially in teaching natural sciences, including physics, it is important for students to acquire not only theoretical knowledge, but also to be able to independently manage their own learning process. In this regard, metacognitive strategies are recognized as an important pedagogical and psychological mechanism in the educational process.

Metacognitive strategies are understood as a set of activities aimed at understanding, controlling, and managing the student's own cognitive process. This concept was first introduced into scientific circulation by the psychologist J. Flavell, who defined metacognition as "knowledge about one's own knowledge." That is, metacognitive activity includes the processes of understanding how a person learns, planning, monitoring the learning process, and evaluating the results.

Theoretically, metacognitive strategies are divided into two main components: metacognitive knowledge and metacognitive control. Metacognitive knowledge is a person's understanding of his or her own level of knowledge, abilities, strengths and weaknesses, and learning methods. For example, if a student can understand which topics in physics he or she is good at and which sections are difficult for him or her, this indicates that his or her metacognitive knowledge has been developed.

Metacognitive control is related to the conscious management of the learning process and includes processes such as planning, observation, and evaluation. At the planning stage, the student determines the learning goal and chooses which strategies will be most effective. During the observation process, he or she constantly monitors his or her activities and identifies aspects that he or she does not understand. At the evaluation stage, the results are analyzed and conclusions are drawn for further activities. These processes serve to develop independent learning skills in the student.

The theoretical foundations of metacognitive strategies are especially important in teaching physics. Because physics is a subject that requires complex concepts, theoretical laws, and logical analysis. The student should not be limited to memorizing ready-made knowledge, but should be able to independently analyze problems, plan solutions, and critically evaluate the results [21]. Metacognitive strategies help to effectively organize these processes.

Psychological research shows that metacognitive activity increases students' self-confidence, strengthens their sense of responsibility for learning, and increases motivation.

When a student begins to control his or her learning process, he or she turns from a passive learner into an active creator of knowledge. This leads to high efficiency, especially in subjects that require logical thinking, such as physics.

Another important aspect of the theoretical foundations of metacognitive strategies is the process of reflection. Reflection means that the student analyzes his or her own activities, realizes his or her mistakes, and seeks ways to correct them. In physics lessons, after the problem-solving process, the student's reflection on questions such as "How did I solve this problem?", "At what stage did I make a mistake?", "What should I do next time?" is an important indicator of metacognitive development.

Also, metacognitive strategies strengthen the individual approach to the educational process. Each student has a unique learning style, and through metacognitive skills, he has the opportunity to choose the strategies that best suit him. This develops the ability to master knowledge more deeply, think independently, and solve problems creatively.

Fizika ta’limida metakognitiv yondashuvning metodologik ahamiyati

The issue of increasing the effectiveness of teaching physics in the modern educational process is closely related not only to providing students with theoretical knowledge, but also to developing their skills in independent thinking, problem analysis, and management of their own cognitive activity. From this perspective, the metacognitive approach is emerging as an important methodological basis in physics education. The metacognitive approach serves to organize students' activities aimed at understanding, controlling, and managing their own cognitive process.

The methodological significance of the metacognitive approach is explained, first of all, by the specific characteristics of physics. Physics is a science based on the combination of complex theoretical concepts, mathematical analysis, and practical experience, and in the process of mastering it, the student is required to have a high level of logical thinking, analytical thinking, and the ability to independently solve problem situations. If in traditional teaching methods the student often participates as a receiver of ready-made knowledge, in the metacognitive approach he is formed as an active subject of the cognitive process [22].

Methodologically, the metacognitive approach allows for a new interpretation of the goals and objectives of physics education. In this case, the educational process is not only aimed at imparting knowledge, but also at developing students' learning skills. The student is not limited to memorizing physical laws, but is taught to understand how they are mastering them, plan the process of solving the problem, analyze their mistakes and independently find ways to correct them. This fundamentally enriches the content and essence of the educational process.

The methodological basis of the metacognitive approach is the processes of planning, control and evaluation. In physics lessons, the student plans how to solve the problem before starting to solve it, monitors his thinking during the solution process, and finally evaluates the result obtained. These stages develop reflective thinking in the student and serve for the conscious assimilation of knowledge. From a methodological point of view, these processes ensure that education is based on the subject-subject principle [23].

Furthermore, the metacognitive approach serves to enhance individualized instruction in physics education. Since every student possesses a unique learning style, metacognitive strategies enable them to recognize their own capabilities, as well as their strengths and weaknesses. Consequently, students select the learning strategies best suited to them, laying the foundation for a deeper and more sustainable mastery of knowledge. From a methodological standpoint, this approach allows for the organization of the educational process in a differentiated and student-centered manner.

Another significant methodological aspect of the metacognitive approach in physics education is its integration with problem-based learning and research activities. In lessons organized around metacognitive strategies, students do not merely limit themselves to applying ready-made formulas; instead, they analyze problems, compare various solution options, and draw conclusions. This fosters the elements of scientific inquiry in students and enables a profound understanding of the essence of physical phenomena (as illustrated in Figure 1).

Figure 1. The structure of metacognitive processes in physics education.

The presented figure is designed as a schematic diagram, aimed at illustrating the structure and interconnectedness of metacognitive activities within the educational process. The diagram consists of several logically linked blocks centered around a core concept.

"n the main section of the diagram, the concept of 'Metacognitive Activity' is positioned, from which several directions branch out. These directions reflect the two primary components of the metacognitive process:

Metacognitive Knowledge

Metacognitive Control

The 'Metacognitive Knowledge' section represents aspects related to the student's awareness of their own knowledge level, learning methods, and their strengths and weaknesses. Within this block, elements such as understanding instructional materials, knowledge of learning strategies, and the effective use of resources are highlighted.

The 'Metacognitive Control' section, on the other hand, illustrates the stages of managing the learning process. It outlines the following core processes:

Planning

Monitoring

Control

Evaluation

These processes demonstrate how students systematically organize their own learning activities and analyze the resulting outcomes.

Figure 1 also highlights the significance of metacognitive activity within the educational process through distinct blocks. These include:

Enhanced mastery of instructional material

Solving complex problems

Effective acquisition of new knowledge

Conscious management of the learning process

The diagram also reflects the application of metacognitive activity within physics education. It illustrates processes such as comprehending complex theoretical concepts, analyzing problems, and monitoring the learning process, thereby emphasizing the vital role of the metacognitive approach in studying physics.

Modern educational technologies—specifically virtual laboratories, interactive software, and simulation tools—further expand the methodological potential of the metacognitive approach. Students independently plan experiments, analyze results, and draw conclusions. Throughout this activity, they develop not only their knowledge of physics but also their skills in managing their own cognitive processes. Consequently, this strengthens the practical orientation of physics education.

From a methodological perspective, the metacognitive approach also necessitates a re-evaluation of the teacher's role. Rather than being a mere source of information, the teacher functions as an organizer, guide, and consultant of the students' cognitive activities. During the lesson, utilizing methods such as question-and-answer sessions, reflexive analysis, and self-assessment serves to consistently develop students' metacognitive skills.

In conclusion, the methodological significance of the metacognitive approach in physics education lies in its ability to enrich the content of the learning process and foster students' skills in independent thinking, analysis, and the conscious management of their own activities. An educational process organized on the basis of this approach serves not only to ensure a robust mastery of subject-specific knowledge but also contributes to the overall intellectual and creative development of the individual.

Practical Implementation Mechanisms (Integration into the Lesson Process)

The practical application of metacognitive strategies in physics education is one of the most vital mechanisms for enhancing educational effectiveness. The synthesis of theoretical knowledge with practical activity, the conscious management of students' own cognitive processes, and the development of independent learning skills are specifically realized through the proper integration of the metacognitive approach into the lesson. Therefore, the systematic implementation of metacognitive strategies across various stages of the lesson is considered a crucial pedagogical task.

The integration of metacognitive strategies into the lesson begins, first and foremost, at the planning stage. The teacher must organize each topic in a way that activates the students' cognitive engagement. At the beginning of the lesson, students are presented with the topic's objectives, expected outcomes, and the specific strategies to be utilized during the learning process. Such an approach enables students to pre-plan their activities and realize which aspects require focused attention at each stage [24].

The use of metacognitive questioning during the lesson is considered one of the most effective mechanisms. For instance, before exploring a new topic, students are asked questions such as: 'What do I already know about this topic?', 'What prior knowledge will I need?', and 'What methods will help me learn this better?' These questions assist students in analyzing their existing knowledge and approaching the learning process consciously. After mastering the topic, a self-assessment process is organized through reflexive questions like: 'What have I learned?', 'Which part was challenging?', and 'How did I correct my mistakes?'

The process of problem-solving in physics lessons creates a favorable opportunity for the application of metacognitive strategies. Before commencing the solution, the student is required to understand the problem, plan the solution path, and select the necessary formulas. During this process, the teacher instructs students to work in the following sequence: analyzing the problem, devising a plan, executing the solution, and verifying the result. Each of these stages serves to develop the student's metacognitive skills.

Another effective method for integrating metacognitive strategies into the lesson is the organization of reflection moments. At the end of each lesson, short reflection sessions are conducted where students analyze their own learning process. They express—either in writing or orally—what they have learned, the difficulties they encountered, and what they should focus on in future lessons. Such activities foster critical thinking and self-assessment skills among students.

The use of modern information technologies is also one of the key mechanisms for implementing metacognitive strategies in practice. Virtual laboratories, interactive simulations, online tests, and multimedia resources enable students to independently verify their knowledge, plan experiments, and analyze results. For example, during virtual laboratory work, a student defines the objective of the experiment, monitors the process, compares outcomes, and draws conclusions. This represents a practical manifestation of metacognitive control.

Group work methods also play a significant role in integrating metacognitive strategies into the lesson process. When students discuss problem-based situations in small groups, they listen to each other's perspectives, defend their own approaches, and reach a collective conclusion. In such processes, students learn to recognize their own thought patterns, analyze solutions, and select the most optimal strategy. Throughout this process, the teacher fulfills the role of a facilitator and consultant.

Another practical implementation mechanism is the introduction of self-assessment and peer-assessment systems. In physics lessons, students are assigned the task of evaluating completed work based on specific criteria. By analyzing their own work, students identify errors and seek ways to rectify deficiencies. This process enhances metacognitive control and serves to reinforce the mastery of knowledge.

Integrating metacognitive strategies into the lesson process also demands new pedagogical approaches from the teacher. Rather than delivering lessons solely in the form of information sharing, the teacher must organize the process based on the principle of managing students' thought activities and directing them toward independent learning. Techniques such as questioning, creating problem-based situations, and the 'think-aloud' method increase students' metacognitive engagement.

Furthermore, the use of specialized learning journals or reflection sheets is recommended for the consistent application of metacognitive strategies. Students record their achievements, difficulties, and future plans for each topic. This method assists them in systematically analyzing their educational activities and encourages continuous self-improvement.

Examples of Applying Metacognitive Strategies in Physics Lessons

Metacognitive strategies can be used to effectively organize the process of learning complex concepts in physics (as shown in Figure 2). For instance, when studying the topic 'Methods of Heat Transfer', the metacognitive approach can be implemented through the following stages:

1. Planning Stage:

Before the lesson begins, students identify their prior knowledge regarding the three methods of heat transfer illustrated in the diagram (conduction, convection, and radiation). They formulate questions for each method: 'How does this method work?' and 'Where is it encountered in daily life?' Students set their own objectives, such as understanding the mechanism and differences between each method.

2. Control and Monitoring Stage:

While studying each method, students constantly check their level of comprehension. For instance, when learning about the process of convection, they should be able to answer the question: "Why does warm air rise?" If they find they do not understand, they modify their learning strategy by seeking additional examples or using animations.

3. Evaluation and Reflection Stage:

At the conclusion of the topic, students test their knowledge by providing examples for each heat transfer method and explaining their practical significance. Then, through self-assessment, they identify which parts are clear and which remain challenging, subsequently creating a plan for future learning.

Outcome:

"Through the metacognitive approach, students do not merely memorize methods of heat transfer; they also gain a profound understanding of their physical mechanisms, the ability to connect them with real-life examples, and the skills to effectively manage their own learning process. This, in turn, facilitates the long-term and practical mastery of physical concepts.

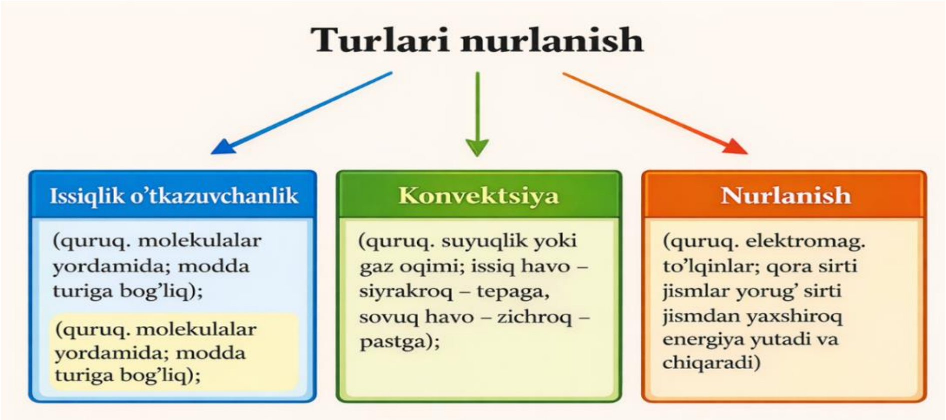


Figure 2. Learning methods of heat transfer using metacognitive strategies

"Figure 2 visually represents the process of systematic and profound mastery of complex physical concepts through the use of metacognitive strategies. The student is not merely memorizing facts but is developing the skills to manage their own learning process, monitor their level of comprehension, and evaluate their own knowledge.

Application of Metacognitive Strategies in Physics Lessons: A Case Study of the 'Methods of Heat Transfer' Topic

Metacognitive strategies are pedagogical approaches aimed at developing a student's ability to understand, plan, monitor, and evaluate their own learning process. In physics education, particularly in teaching complex concepts such as "Methods of Heat Transfer," the application of metacognitive strategies enables students to gain a deeper mastery of the subject, develop independent thinking skills, and apply their knowledge in real-life situations.

Core Stages of Metacognitive Strategies

1. The Planning Stage

In the planning stage, before engaging with the topic, students assess their current level of knowledge, establish learning objectives, and select effective strategies for studying the subject matter.

Practical Examples:

Identifying Prior Knowledge: Students are presented with the following questions regarding the topic "Methods of Heat Transfer": What is heat? How does heat spread? What examples of heat transfer do you observe in your daily life? Students record their answers and discuss them in class. Through this process, they determine their existing level of proficiency.

2. Goal Setting: Students establish the following objectives for learning the topic:

Understanding the three primary methods of heat transfer (conduction, convection, and radiation).

Identifying the mechanisms and key differences of each method.

Providing practical, real-life examples for each mode of heat transfer.

3. Strategy Selection: Students select the following strategies to master the topic:

Reading the textbook and supplementary materials.

Conducting practical experiments (e.g., comparing conduction by heating metal and wooden objects).

Learning through visual aids (images, diagrams, and videos).

Organizing group discussions and collaborative projects.

2. The Monitoring Stage

In the monitoring stage, students observe their own learning process, verify their level of comprehension, and, if necessary, modify their strategies.

Practical Examples:

1. Self-Checking: While studying each method of heat transfer, students ask themselves the following questions: Do I fully understand the mechanism of this method? How can I distinguish this method from others? What real-life examples can I provide for this method? If the answers are unsatisfactory, students refer to supplementary materials or seek assistance from the teacher.

2. Tracking Progress: Students monitor their knowledge through the following methods: Preparing a short written or oral summary for each method; comparing heat transfer methods using diagrams; and recording and analyzing experimental results.

3. Modifying Strategies: If a student struggles to understand a particular method, they adjust their strategy by: Increasing their use of visual materials; repeating practical experiments; or formulating additional self-questioning.

3. Assessment Phase

During the assessment phase, students test their knowledge, review the topic, and make plans for future learning.

Practical examples:

1. Self-assessment: Students assess their knowledge in the following ways: They complete test tasks and check their answers themselves. They answer questions related to the topic (e.g., “What is the difference between heat conduction and radiation?”). They identify heat transfer methods in real-life situations (e.g., what heat transfer methods work when boiling tea in a samovar?).

2. Reflection: Students reflect on the learning process: What was my best learning strategy? Which parts were difficult for me and how did I overcome them? What do I need to change when studying future topics?

3. Future planning: Students make plans for future topics based on their experiences: What strategies were effective? What additional resources are needed? How can they reinforce their knowledge?

Metacognitive Lesson Plan on the Topic: "Methods of Heat Transfer" Lesson Structure:

1. Planning Stage (15 minutes)

- Engaging Students with the Topic: Starting with a general question: "What is heat?"

- Activating Prior Knowledge: Recording the students' initial understanding and concepts regarding the topic.

- Goal Setting: Establishing individual learning objectives for each student.

- Strategy Selection: Offering students various learning methods (individual work, pair work, or group work).

2. Learning New Material (30 minutes)

- Sequential study of the three methods of heat transfer:

- Thermal Conduction: Transfer of heat through matter particles.

- Convection: Transfer of heat through the flow of liquids or gases.

- Radiation: Transfer of heat through electromagnetic waves.

- Metacognitive questioning during the study of each method: "How does this work?", "Where is it encountered in life?", and "How does it differ from other methods?"

3. Practical Activities (25 minutes)

- Hands-on experiments for each heat transfer method:

- Comparing conduction by heating objects made of metal and plastic.

- Observing the process of convection while heating water.

- Understanding radiation using solar rays.

- Monitoring the experimental process and analyzing results.

4. Evaluation and Reflection (20 minutes)

- Knowledge Check: A short test or Q&A session.

- Reflection Activity: Each student provides feedback on their own learning process.

- Planning Next Steps: Developing strategies for studying future topics.

Advantages of Metacognitive Strategies in the Educational Process

1. Developing Independence

Students learn to manage their learning process autonomously. They discover how to approach different materials, identify when to seek assistance, and learn the methods for evaluating their own knowledge.

2. Deep Understanding

Metacognitive strategies allow students to move beyond surface-level learning toward a profound understanding of the subject. For example, rather than merely knowing the names of heat transfer methods, they comprehend their physical mechanisms, distinctions, and practical applications.

3. Ability to Apply Knowledge Practically

Students develop the capacity to apply their knowledge in real-life situations. This includes identifying heat transfer methods in household appliances, construction, and natural phenomena

4. Increasing Motivation

Seeing their own progress provides students with confidence and increases their interest in learning. Through metacognitive strategies, students can clearly visualize their successes.

Problematic Situations and Solutions

1. Difficulties in Students' Adoption of Metacognitive Strategies

Some students are accustomed to traditional teaching methods and may struggle to adopt metacognitive strategies.

Solution: Step-by-step instruction, starting with simple metacognitive tasks initially.

2. Time Constraints

Metacognitive strategies can require more time than traditional lesson methods.

Solution: Applying strategies during specific parts of the lesson and carefully planning the lesson schedule.

3. Teacher Preparedness

Some teachers may lack experience in implementing metacognitive strategies.

Solution: Conducting specialized training for teachers and preparing practical manuals.

The application of metacognitive strategies in physics lessons, particularly in teaching complex topics such as 'Methods of Heat Transfer,' enables students to achieve a deeper mastery of the subject, develop independent thinking skills, and apply their knowledge in practical life. These strategies empower students not only to acquire knowledge but also to master the skills of managing, analyzing, and evaluating their own learning process. By implementing these strategies into the educational process, teachers can facilitate a profound and continuous understanding of physical concepts. To enhance the effectiveness of physics education in the future, it is essential to more broadly apply metacognitive approaches and integrate them into the curriculum.

Figure 3. Visual and systematic representation of "Internal Energy" and fundamental concepts of thermodynamics

"Figure 3 provides a visual and systematic presentation of the core concepts of 'Internal Energy' and thermodynamics in physics. The diagram consists of two primary sections: the upper portion illustrates the types of energy and the concept of internal energy, while the lower portion outlines the methods for changing internal energy.

In Figure 3, the formulas for kinetic and potential energy are displayed alongside directional arrows, which clearly express the direction and nature of energy transformation.

Internal energy is defined as the sum of both types of energy, revealing the fundamental nature of the concept.

Following the horizontal divider, the diagram illustrates the basic principles of thermodynamics. Here, two methods of changing internal energy are emphasized: mechanical work and heat exchange. Two primary modes of heat transfer (conduction and radiation) are highlighted separately, underscoring their significance.

At the bottom of Figure 3, the formula for the First Law of Thermodynamics is presented (\Delta U = A + Q), which serves as the practical expression of the law of conservation of energy in physics. The components of the diagram are arranged in a logical sequence, allowing students to master complex physical concepts step-by-step and through visual means. This educational material not only provides theoretical knowledge but also assists students in perceiving the interconnections between different concepts.

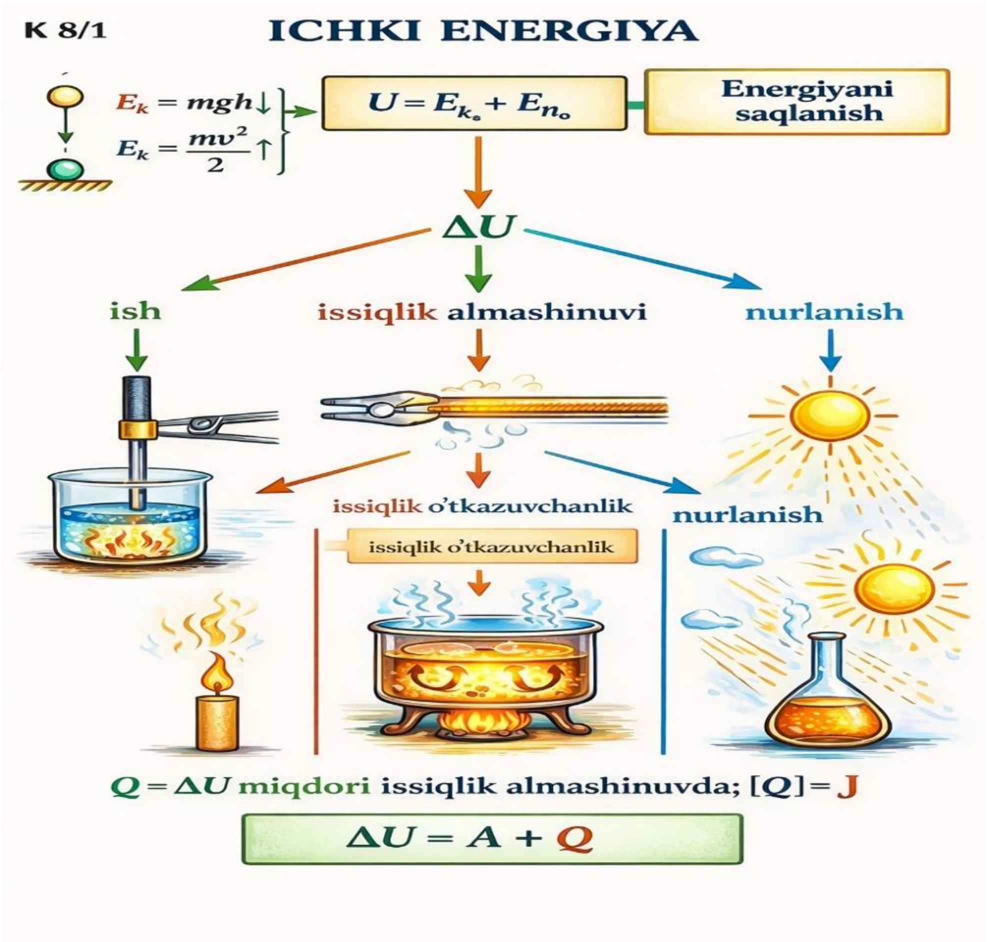


Figure 3. Internal energy and fundamental principles of thermodynamics.

The following Figure 4 serves as an effective educational model for teaching the states of matter and thermal processes in physics, based on a methodological approach. The graph illustrates the sequential stages of a substance's transition through solid, liquid, and gaseous states by showing temperature changes over time, which enables the development of systematic and logical thinking in students.

Methodologically, this diagram is based on the principles of step-by-step learning, visual analysis, and reflective thinking. During the lesson, the teacher begins the analysis of the graph at segment A–B. At this stage, the heating of the substance in its solid state is shown, and students begin to understand cause-and-effect relationships by addressing the question: 'Why is the temperature increasing?' The horizontal lines at segments B–C and D–E are methodologically significant, as they serve to explain why the temperature remains constant during phase changes. In this process, the concept of latent heat is introduced.

Segments C–D and E–F are used to analyze the increase in temperature in the liquid and gaseous states, respectively. At these stages, students are encouraged to independently interpret the graph and justify their conclusions. In line with the metacognitive approach, this develops the students' skills in monitoring and evaluating their own knowledge.

The second half of the graph (F–Q) represents the cooling process. In this section, students conduct an analysis based on comparisons with their prior knowledge. According to the methodological approach, at the conclusion of the lesson, students are required to draw a comprehensive summary based on the graph and express the laws governing phase transitions.

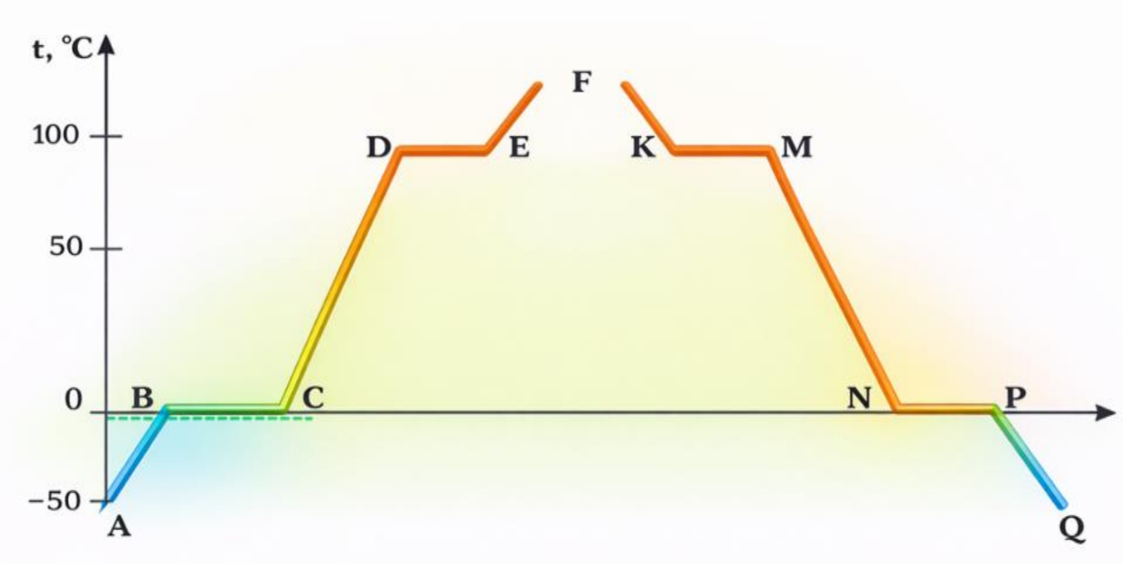


Figure 4. Graph of changes in states of matter during heating and cooling processes

AB – Heating of a solid

BC – Melting of a solid

CD – Heating of a liquid

DE – Boiling of a liquid

EF – Heating of vapor (steam)

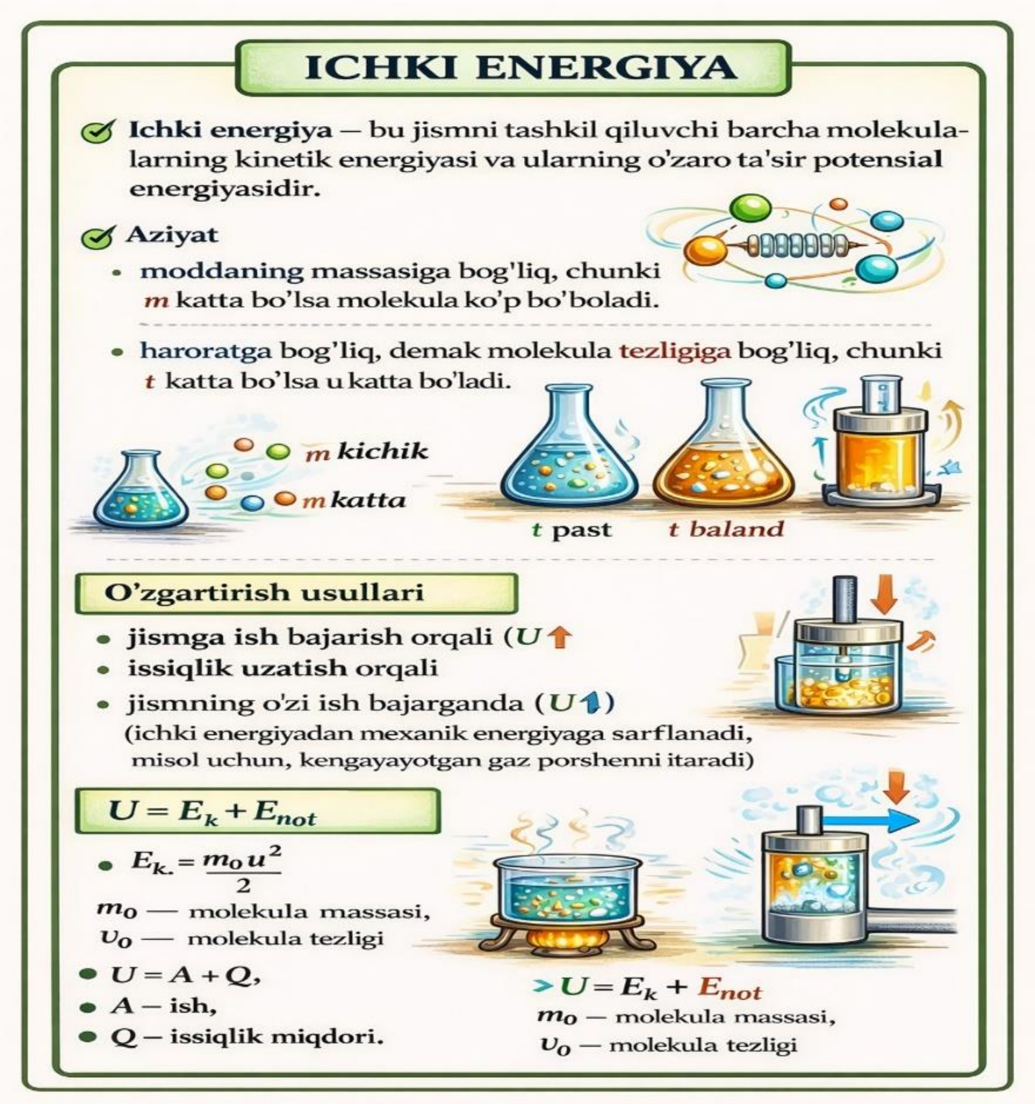
FK – Cooling of vapor (steam)

KM – Condensation of vapor

MN – Cooling of a liquid

NP – Crystallization (freezing) of a liquid

PQ – Cooling of a solid



ICHKI ENERGIYA

✓ **Ichki energiya** — bu jismni tashkil qiluvchi barcha molekulalarning kinetik energiyasi va ularning o'zaro ta'sir potensial energiyasidir.

✓ **Aziyat**

- moddaning massasiga bog'liq, chunki m katta bo'lsa molekula ko'p bo'ladi.
- haroratga bog'liq, demak molekula tezligiga bog'liq, chunki t katta bo'lsa u katta bo'ladi.

O'zgartirish usullari

- jismga ish bajarish orqali (U↑
- issiqlik uzatish orqali
- jismning o'zi ish bajarganda (U↑)

(ichki energiyadan mexanik energiyaga sarflanadi, misol uchun, kengayayotgan gaz porshenni itaradi)

$U = E_k + E_{not}$

- $E_{k.} = \frac{m_0 u^2}{2}$

m_0 — molekula massasi,
υ_0 — molekula tezligi

- $U = A + Q$,
- A — ish,
- Q — issiqlik miqdori.

> $U = E_k + E_{not}$

m_0 — molekula massasi,
υ_0 — molekula tezligi

Figure 5. Internal energy: definition, relationships, and methods of change.

Figure 5 comprehensively covers the topic of internal energy, one of the important concepts in physics. It provides a clear and illustrative description of the definition of internal energy, the factors that affect it, and the methods of changing it. According to the figure, internal energy is the sum of the kinetic energy of all molecules that make up a body and the potential energy of their interaction. This definition reveals the microscopic nature of internal energy.

The diagram shows how internal energy depends on the mass and temperature of a substance. If the mass of a substance is large, the number of molecules in it will also be large, which will result in an increase in internal energy. Also, when the temperature increases, the speed of movement of the molecules increases, and their kinetic energy also increases.

Figure 5 clearly illustrates this relationship through the “t low” and “t high” cases.

The next section presents methods for changing internal energy. These are done by doing work on a body and by transferring heat. For example, when a gas is compressed or expanded, mechanical work is done and the internal energy changes accordingly. It also shows that internal energy increases or decreases through heating or cooling processes.

Figure 5 also provides a mathematical expression of internal energy using formulas: it is emphasized that it is equal to the sum of the kinetic and potential energies of the molecules. Overall, this figure serves to provide a deep understanding of the concept of internal energy from both a theoretical and practical perspective.

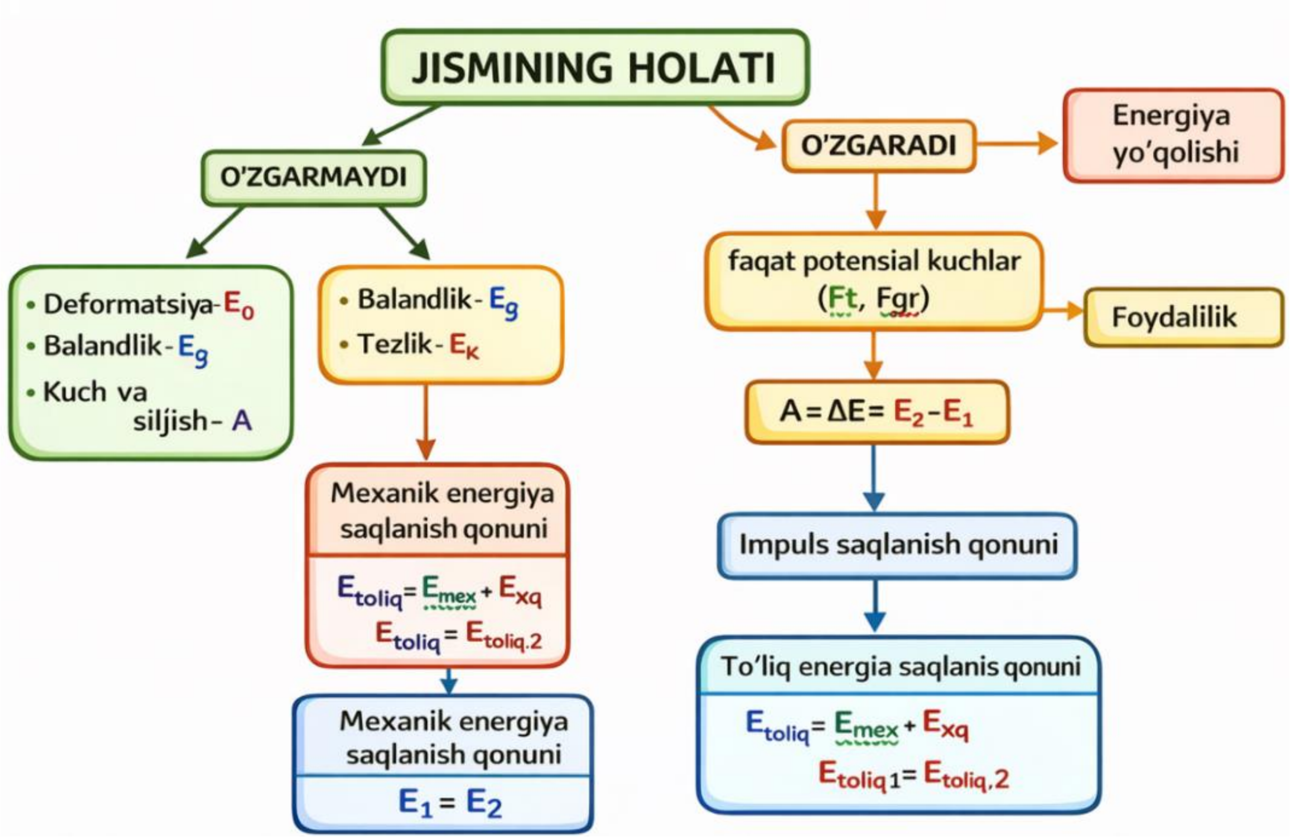


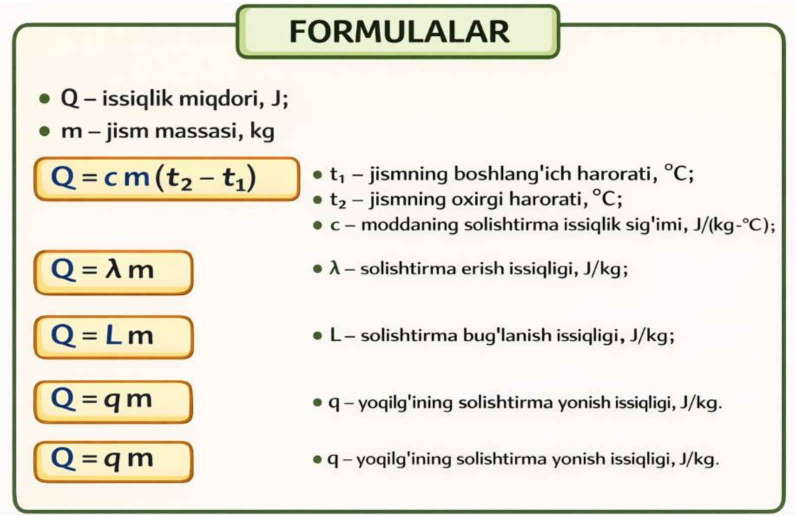
Figure 6. Methodological scheme for studying the laws of motion and conservation of energy.

Figure 6 schematically illustrates the basic physical laws related to mechanical energy and changes in the state of a body. The diagram begins with the concept of "state of a body" and is divided into two main cases related to the conservation or change of energy: processes in which the state of the body does not change and processes in which the state of the body changes.

The left part of Figure 6 shows the cases where the state of the body does not change. Here, the deformation energy, the height energy, and the work done by the displacement by the force are mentioned. If the height and velocity of the body do not change, its mechanical energy is conserved. Mechanical energy consists of the sum of the height (potential) energy and the velocity (kinetic) energy, and in a closed system it remains a constant quantity. In this case, the law of conservation of mechanical energy applies, that is, the initial and final energies of the system are equal.

The right part of Figure 6 illustrates the processes in which the state of a body changes. In such cases, energy can be lost or transformed into another form. If only potential forces act, the work done is equal to the change in energy. Here, the relationship between work and energy is shown by the formula A = ΔE. The law of conservation of momentum and the law of conservation of total energy are also presented. These laws ensure the conservation of total energy even when mechanical energy is exchanged with other types of energy.

Overall, the picture clearly reveals the logical connection between mechanical energy, work, momentum, and the laws of conservation of energy.



FORMULALAR

- Q – issiqlik miqdori, J;
- m – jism massasi, kg

$Q = c\,m(t_2 - t_1)$
- t_1 – jismning boshlang'ich harorati, °C;
- t_2 – jismning oxirgi harorati, °C;
- c – moddaning solishtirma issiqlik sig'imi, J/(kg·°C);

$Q = \lambda m$
- λ – solishtirma erish issiqligi, J/kg;

$Q = Lm$
- L – solishtirma bug'lanish issiqligi, J/kg;

$Q = qm$
- q – yoqilg'ining solishtirma yonish issiqligi, J/kg.

$Q = qm$
- q – yoqilg'ining solishtirma yonish issiqligi, J/kg.

Figure 7. Methodological table for studying formulas for calculating the amount of heat.

Figure 7 presents the main physical formulas used in calculating thermal phenomena in a systematic and understandable form. It clearly shows the concepts related to the amount of heat, their physical meaning and units of measurement. It is emphasized that Q is the amount of heat as the central concept, and it is expressed in joules (J). It is also noted that m is the mass of the body, measured in kilograms.

The main part of Figure 7 presents several important formulas. The first formula, $Q=c\cdot m\cdot(t_2 - t_1)$, is used to determine the amount of heat released during the heating or cooling process of a body. The difference between the initial and final temperatures plays a key role here. This formula explains how much heat is required to bring different bodies to the same temperature through the specific heat capacity of a substance.

The following formulas are related to phase changes. The formula $Q=\lambda\cdot m$ is used to determine the amount of heat absorbed during the melting of a substance, and $Q=L\cdot m$ is used to determine the amount of heat required during the evaporation process. It is understood that in these processes the temperature does not change, and the heat is spent on changing the internal state of the substance.

Also, the formula $Q=q\cdot m$ is given to calculate the heat released during the combustion of fuel. This formula is important in the fields of energy and technology. In general, the picture is an important methodological material for understanding thermal processes, solving problems, and consolidating theoretical knowledge.

Scientific and theoretical results

In this study, the role of metacognitive strategies in improving the effectiveness of physics teaching was scientifically and theoretically substantiated. The analysis shows that the metacognitive approach in physics education serves not only to transfer knowledge, but also to form students' competencies for consciously planning, controlling and evaluating their own cognitive activity. Metacognitive knowledge (declarative, procedural and conditional knowledge) and metacognitive control (planning, monitoring and evaluation) were identified as the main components of metacognitive activity, and their role in the study of physics was scientifically elucidated.

The results of the scientific-theoretical analysis have shown that metacognitive strategies are an important factor in mastering complex topics in physics (for example, mechanical energy, thermal phenomena, phase changes, electricity and magnetism). In particular, when using a metacognitive approach in the process of working with graphs, formulas and schematic models, students focus not only on the result, but also on the solution process. This expands the possibilities of a deeper understanding of cause-and-effect relationships, identifying and correcting errors, as well as applying knowledge in new situations.

Theoretical results show that metacognitive strategies activate students' self-regulated learning mechanisms. In this case, the student can realistically assess his or her level of knowledge, understand which topics he or she is struggling with, and select appropriate learning strategies. These processes are important in solving problem situations in physics, solving problems, and analyzing laboratory experiments. Psychological studies also confirm that metacognitive activities increase students' confidence, reduce stress, and increase motivation to study.

Theoretical generalizations based on the dissertation materials showed that the metacognitive approach enriches the methodological foundations of physics education. In particular, it was scientifically substantiated that the systematic introduction of metacognitive strategies in teaching physics in general secondary schools can deepen the content of education, ensure students' conscious assimilation of knowledge, and strengthen interdisciplinary integration. The metacognitive approach stimulates access to the higher levels of Bloom's taxonomy (analysis, evaluation, creativity), which enhances the practical application of theoretical knowledge in physics.

Another scientific and theoretical result is that metacognitive strategies change the nature of the interaction between the teacher and the student. While in traditional lessons the teacher is the leader as a source of knowledge, in the metacognitive approach he plays the role of a guide and facilitator. The student, as an active subject, controls his own learning process. This increases the effectiveness of physics lessons and forms the skills of independent thinking and reflective analysis in students.

Also, the results of scientific and theoretical analysis have shown that the use of metacognitive strategies in combination with innovative pedagogical technologies (virtual laboratories, simulations, interactive models) in physics education is highly effective. Such integration develops students' visual, logical and analytical thinking, helping them to understand complex physical processes as a holistic system.

In general, the obtained scientific and theoretical results confirm that the use of metacognitive strategies in teaching physics is an important scientific basis for increasing educational effectiveness. The metacognitive approach serves to develop students' conscious assimilation of knowledge, self-control, and independent learning activities. These results serve as an important scientific and theoretical foundation for improving the methodology of physics education and forming a competitive and independent-thinking personality in line with modern educational requirements.

Statistical analysis of results

As part of the study, pedagogical experimental and test work was conducted to determine the effectiveness of metacognitive strategies in teaching physics, and the results were analyzed using mathematical and statistical methods. The experiment involved students in grades 7–9 of general secondary schools, who were divided into an experimental group and a control group. In the experimental group, physics lessons were organized based on metacognitive strategies (planning, monitoring, reflection, self-assessment), while in the control group, traditional teaching methods were used.

At the initial stage of statistical analysis, the initial knowledge level of students was determined, and it was confirmed that there was no significant difference between the two groups. This served as an important factor in ensuring the reliability of the experimental results. The results of the initial and final test were evaluated using the arithmetic mean (M), variance (D) and standard deviation (σ). According to the results of the analysis, it was found that the final mastery indicators of students in the experimental group significantly increased compared to the initial state.

The dynamics of average scores showed that the growth of knowledge in the experimental group was higher than in the control group. In particular, the average level of mastery in the experimental group increased with a statistically significant difference ($p < 0.05$), while in the control group the growth was relatively low. This difference was tested using the Student's t-test, scientifically confirming the effectiveness of lessons in which metacognitive strategies were used.

Also, the results of the questionnaires on students' metacognitive skills (planning, monitoring, evaluation) were analyzed based on percentages. According to the results, the proportion of students with high and medium levels of metacognitive skills in the experimental group significantly increased, while the percentage of low levels decreased. This indicates that students' self-regulated learning abilities have developed.

The results of the correlation analysis showed a positive correlation between the level of metacognitive skills and the achievement indicators in physics ($r > 0.6$). This correlation proves that metacognitive strategies have a positive impact not only on the level of knowledge of students, but also on their ability to think independently and solve problem situations.

In general, the results of the statistical analysis scientifically substantiated the fact that the use of metacognitive strategies in teaching physics increases educational effectiveness. The obtained data confirmed the reliability of experimental work and showed the feasibility of widely introducing the metacognitive approach into the practice of physics education.

CONCLUSION

This article analyzes the role of metacognitive strategies in improving the effectiveness of physics teaching from a theoretical and practical perspective. The materials used in the study, including formulas for heat processes and schematic images representing mechanical energy, internal energy, and the state of the body, have shown that they are a convenient didactic tool for deepening students' cognitive processes in teaching physics. When these tools are combined with a metacognitive approach, not only the level of knowledge of students, but also their self-control, analysis, and evaluation skills, significantly develop.

The analysis shows that metacognitive strategies help students consciously master complex concepts in physics lessons. For example, when working with formulas, the student not only performs calculations, but also begins to understand which formula is used when and why. This leads to the formation of declarative, procedural and conditional knowledge. Also, studying topics based on graphs and diagrams develops students' visual thinking and helps them understand physical processes as a whole system.

Another important aspect of metacognitive strategies is the formation of reflection skills in students. At the end of the lesson, the student seeks answers to questions such as “what did I learn?”, “where did I go wrong?”, “which strategy was more effective?” As a result, the learning process turns from passive reception into active, conscious activity. This is especially important in physics, since science requires logical thinking, the identification of cause-and-effect relationships, and the analysis of experimental results.

The results of the study show that in physics lessons organized on the basis of a metacognitive approach, the level of student mastery increases, interest in the subject increases, and the need for independent learning is formed. While traditional lessons emphasize more on providing ready-made knowledge, in lessons using metacognitive strategies, the student “learns how to learn” knowledge. This has a positive effect on long-term educational outcomes.

In conclusion, the use of metacognitive strategies in teaching physics is one of the important factors in increasing educational effectiveness. Combining educational materials such as formulas, graphs and schematic images with metacognitive activities develops students' scientific thinking, critical and reflective thinking. This serves to form a person who is able to think independently and manage his own knowledge, in line with the requirements of modern education. Therefore, the widespread introduction of a metacognitive approach in the practice of teaching physics is a pedagogically relevant and promising direction.

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