METHODS OF SCIENTIFIC KNOWLEDGE AND RESEARCH IN THE CONTENT OF SECONDARY EDUCATION ON PHYSICS

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Abstract. Based on a systemic approach, the content of the course of Physics can be expressed through its components, among which there are the following ones: scientific knowledge and methods of learning; questions for self–testing; exercises; assignments; examples of problem solving aimed at forming knowledge and experience of cognitive methods application in familiar situations; creative tasks for the development of the experience of theoretical and experimental research; means of motivating by the content and by the process of learning. Each type of contents implements the relationship of scientific knowledge and methods of cognition of objects at different levels of theoretical generalizations.

Key words: general secondary education, content, system, course of Physics, kinds of contents, scientific knowledge, methods of learning, types of learning activities, experience of creative activity, motivation by content, motivation by process.

1. Introduction. The content of education in didactics is defined as the transfer of the social experience of society to the younger generation. Social experience embodies culture, the broad meaning of which1 is the socially progressive creative activity of man in all its spheres. Social experience consists of certain elements – types of content: knowledge about nature, society, technology, man, methods of cognitive activity; experience in the implementation of known methods of activity; experience of creative activity embodied in special intellectual procedures; experience of emotional–valuable attitude to reality [1; 4].

In the methodology of teaching physics, these four types of content can be specified taking into account the peculiarities of the cognitive activity of students when studying a high school physics course. The course content is a systemic concept that has the following types:

–scientific knowledge and methods of cognition of physics;

–questions for self–control, exercises, tasks, examples of problem solving as a means of transferring the experience of applying knowledge and methods of cognition to students in familiar situations;

–creative tasks, the implementation of which requires the use of educational activities characteristic of theoretical and experimental research;

–means of motivation by the content and process of educational activity.

The types of content of a physics course significantly affect the development of students' intellectual and creative abilities, which are characterized by the presence of special strategies for educational activity, its individual style, highly structured knowledge, and criticality to the results of their own educational work.

2. Discussion. Let's consider the types of content of the physics course on the example of the author's line of textbooks and the corresponding educational and methodological set in high school physics [5; 6].

The first type of content "Scientific knowledge and methods of cognition" of the physics course is presented as two interrelated subsystems: scientific knowledge and methods of cognition. The subsystem "Scientific Knowledge" is reflected in curricula, textbooks and methodological manuals in certain forms of expression, the main of which are physical phenomena, bodies, matter, physical concepts (including physical quantities), laws, theories, the physical picture of the world. The section of physics – mechanics, molecular physics, electrodynamics, quantum physics – has a certain composition of scientific knowledge, expressed through the above forms. Each of them has the property of systemicity. For example, the presentation of educational material on a physical quantity includes the following elements: the result of observing the property of an object characterized by a physical quantity; object model; definition formula; unit of measurement in SI; the physical meaning of the quantity; measurement method; examples of use in technology. This scheme of element–by–element analysis of a physical quantity is approximate, since physical quantities not only have common properties, but also have their own characteristics.

So, when getting acquainted with the physical picture of the world in the course of the ninth grade, categories are distinguished among the concepts. They reflect in cognition the most general and essential properties of objects. The categories include concepts of law, interaction, movement, energy. In the course, they are presented in specific terms of the subject, for example, Newton's laws, strong interaction, thermal motion of the molecules of matter, the energy of the electromagnetic field. These forms of expression of scientific knowledge are included as elements of the above categories.

A new addition to the type of content "Physical Methods of Investigating Nature" in physics textbooks is the introduction of special chapters devoted to methods of understanding nature. Table 1 shows a fragment from the program of approximate thematic planning of the chapter "Physical Methods for the Study of Nature" of the seventh grade physics course [7]. This chapter is an introduction to the course of physics of the first stage.

Table 1.

Thematic planning of the chapter "Physical methods for the study of nature"

The main content of the topic "Physical methods for the study of nature"	**Characteristics of the main activities of the student (at the level of educational activities)**
Physics is the science of nature. Objects of study of physics. Experiment and modeling are the main methods of studying nature. Physical quantities. International system of units. Measuring instruments. The density of matter. Indirect measurements of the density of matter. The discovery of laws is the task of physics. Physical theories are a system of scientific knowledge.	Give examples of objects of study of physics (physical phenomena, physical body, substance, physical field). Observe and analyze physical phenomena (fix changes in the properties of objects, compare and generalize). To get acquainted with the experimental method of research (reproduce, fix changes in the properties of an object, analyze the results) and the modeling method (identify the essential and secondary in the study of physical phenomena). Use physical models (material point, mathematical pendulum, Copernican model of the

Physics is a developing science. Connection of physics with other natural sciences.	solar system) to explain mechanical phenomena. Give examples of basic and derived SI units. Determine the main characteristics of measuring instruments (measurement limit, scale division value). Measure the dimensions of a flat body, taking into account the maximum absolute and relative measurement errors. Compare the density values of some substances according to the table.

As follows from the table, when studying the chapter "Physical Methods for Investigating Nature", students get acquainted with the main methods of cognition – physical experiment and modeling. Under the method (from the Greek metod – “way of cognition”) in physics they understand the method of activity, which is reduced to certain rules, techniques, norms of cognition and a set of educational mental and experimental actions that students need to perform to achieve the pedagogical goal and corresponding tasks.

The purpose of the method is to organize and regulate the learning activities of students in physics, which are revealed in the program by describing the characteristics of the main activities. Thus, the textbook details the composition of one of the most important experimental methods of physics – the method of direct measurement of physical quantities, the purpose of which is to find the numerical value of a physical quantity using measuring instruments. According to the rules of their application, in the process of measurement, it is necessary to perform the following types of actions: find the measurement limit and division value of the device, calculate the absolute error, record the measurement result of the value, taking into account the absolute (or relative) error.

In the chapter "Physical Methods for Investigating Nature", students only get acquainted with the methods of physical experiment and modeling (Table 1). Students must master the following activities of a physical experiment: reproduce, record changes in the properties of an object, analyze the results, measure the dimensions of a flat body, taking into account the maximum absolute and relative measurement errors. Familiarization with the modeling method means mastering the following educational activities: highlight the essential and secondary in the study of physical phenomena, use physical models – a material point, a mathematical pendulum, a model of the solar system according to Copernicus – to explain mechanical phenomena [8].

When studying the topics of the course, knowledge and skills develop, learning activities that are characteristic of experiment and modeling become more complicated. For example, the activity of studying the theoretical law of universal gravitation involves the following actions: to get acquainted with the history of its discovery, to analyze the mathematical record of the law, to understand the physical meaning of the gravitational constant, the conditions for the applicability of the formula of the law of universal gravitation. The study of an empirical law, for example, Hooke's law, provides for other types of educational actions than actions in the assimilation of a theoretical law. To study Hooke's law means to observe elastic deformation, experimentally investigate the dependence of the

elastic force on the elongation of the body, analyze the results of the experiment, and determine the limits of the law's applicability.

The introduction of new topics on the methods of scientific knowledge, the characteristics of the main types of activities of students at the level of educational actions into the course of physics sets a new strategy for learning activities in the lesson, which is characterized by the rapid development of educational material, the high success of its implementation; advancement of specific goals of activities due to a deeper knowledge of the subject.

The next type of content for a physics course is the content of questions for self–control, exercises, tasks, examples of solving problems in textbooks. This type of content is a means of shaping students' experience of applying cognitive methods in familiar situations.

The solution of any problem requires the use of certain methods of cognition. Any method, including the method of solving problems, can be considered as a model of activity containing a goal, a sequence of certain educational actions and means to achieve the goal. Questions to the texts of paragraphs of textbooks give some orientation in the texts of their content; analysis of problem solving – description of the algorithm for solving them for the application of laws and theories; performance of tasks and exercises–self–control of the quality of assimilation of mental actions when solving problems in a familiar situation. So, in the paragraph "Methods for solving problems on the application of conservation laws in mechanics" of the course of physics of the ninth grade, an algorithm for solving problems on the application of the law of conservation of total mechanical energy is analyzed. In questions for self–control, it is proposed to talk about the system of actions in solving problems for the application of the law of conservation of total mechanical energy. An analysis of an example of solving the problem reveals the steps that must be taken to find the work of the friction force applied to the car during emergency braking until it comes to a complete stop. Tasks and exercises include all the main types of presentation of situations: through graphs, experiments, formulas (equations), analysis of the movement of vehicles that are close to real conditions.

For the successful mastering of the types of educational activities, scientific knowledge and methods of cognition in senior secondary school, it is important to acquaint students with the general methods characteristic of all natural sciences and physical research methods. The study of the physics course of the tenth grade (second stage) begins with the introductory chapter "Method of scientific knowledge", the educational material of which is devoted to the methodological issues of physics. Students get acquainted with two main levels of knowledge of nature – empirical and theoretical (Table 2). These levels are closely related and differ significantly from each other. At the empirical level, sensual cognition, living contemplation, directed directly at the object under study, prevails. Empirical generalizations use rational forms of cognition – judgments, concepts, ideas, measurements of quantities, but they have a subordinate meaning. The investigated object is reflected mainly from the side of its external properties, accessible to sensory knowledge.

As follows from table 2, the main methods of cognition characteristic of the empirical level are the collection of facts, their primary generalization, description of the observed experimental data, their systematization and classification.

Table 2.

Components of the process of scientific knowledge	levels of knowledge	
	Empirical	Theoretical
Target	Description of a physical phenomenon; properties of matter, physical field	Explanation of the phenomenon, properties of matter, physical field; event prediction
An object	Physical phenomenon; matter, physical field	The essence of a physical phenomenon, physical field, properties of matter
Types of generalization (examples)	Empirical law, idea, hypothesis	Theoretical law, hypothesis, idea
Methods of knowledge (examples)	Observation, description, classification, comparison, measurement	Climbing from: abstract concepts to scientific fact; abstract understanding of theory to a concrete, more complete understanding of phenomena
General logical methods of cognition (examples)	Observation, description, classification, comparison, measurement	Analysis, synthesis, induction, deduction, modeling

In modern science, the main types of generalization are physical theories and the physical picture of the world as the basis of the natural science picture. The theoretical level of knowledge and the empirical method of research are interconnected. This relationship is manifested in the fact that experience is planned and constructed by theory. An experiment represents a planned action, each step of which is guided by a theory. The theoretical level of knowledge is characterized by the predominance of such forms of generalizations as concepts, laws, and theories. At the same time, living contemplation, sensory cognition becomes a subordinate, but important aspect of the cognitive process. The main goal of the theoretical level of knowledge is the achievement of objective truth in all its concreteness and completeness of content. Cognitive techniques and methods are used to solve this problem. These include idealization – mental objects, synthesis – combining the received data into a system as a result of their analysis and comparison with its other elements, deduction – the movement of knowledge from the general to the particular, the ascent of the abstract to the concrete.

An important feature of scientific knowledge should be noted: empirical and theoretical knowledge have common logical forms of expression, for example, a law, a hypothesis, an idea. On their basis, more complex forms of rational knowledge are built – a physical theory, a physical picture of the world. The empirical and theoretical methods of cognition are also characterized by general methods: analysis, synthesis, induction, deduction, modeling (empirical and theoretical), interpretation.

In the course of physics, students get acquainted with the philosophical principles (methods), general scientific and often scientific methods of physics. Philosophical methods, unlike others, are not rigid prescriptions, regulators of actions, but are a system of “soft” principles, operations, techniques and have a general character. Thus, the principles of

historicism and contradiction play the role of a method of studying nature. They are not described in strict terms of logic and experiment, they are not amenable to formalization and mathematization.

General scientific approaches and methods are developed on the basis of general scientific concepts, for example, "model", "probability", "system", "activity". These concepts define the names of general scientific methods – modeling, probabilistic, systematic, activity approach. These methods lend themselves to formalization, refinement by means of mathematical theory, symbolic logic.

Often scientific methods are related to specific sciences, such as physics. Such methods are the Galilean method, the coordinate and vector methods in mechanics, the statistical and thermodynamic methods in molecular physics [2], the superposition principle in mechanics and electrodynamics, the Huygens principle and the spectral method in optics, and the probe method in quantum physics.

Creative tasks of theoretical and experimental research constitute the third type of course content. Creative tasks are a form of active learning research and construction. To complete these tasks, the student must identify the object of study, determine the theoretical model, mentally imagine the object of study and conduct a thought experiment with it. There is a set of statements that contain a description of the object of study and at the same time serve as a means of predicting the results of a real experiment. At the same time, students' ideas about the structure of research and design activities are formed.

B.C. Stepin and L.M. Tomilchik in the scientific knowledge of physics distinguishes layers of model schemes that define the object of study. These schemes include empirical schemes, primary models of theoretical explanation, schemes underlying the developed theories [3].

If we take the objects of their research as the basis for classifying tasks, then all tasks can be divided into three groups: 1) empirical, 2) tasks of theoretical explanation, 3) tasks, model schemes of which lie at the foundation of developed theories – mechanics, molecular physics, electrodynamics, quantum physics.

Empirical tasks include those that use special models of the empirical level of cognition. In research tasks of this level, the experiment is schematized by replacing real objects with empirical model objects, for example, in the form of diagrams, drawings, drawings of the experimental setup. In the task, such models are provided with some description. An example of the first group is a creative task from the ninth grade physics course (Table 3).

The model objects in this problem are an electric circuit, a research scheme, a drawing. They reflect the connections and interactions of the components of the model scheme of empirical explanation, as well as the results of mental experience. The second group includes tasks of theoretical explanation, in which mental experience with ideal models acts as an object of study. Consider an example of the second group of tasks (Table 3).

The solution to this problem is reduced to a model for explaining the action of a flashlight. This model is based on the phenomenon of electromagnetic induction. In this case, abstract objects are used: "conductors", "lines of magnetic induction", from which a model of theoretical explanation is built. The dynamic model of the theoretical explanation reflects the relationship between objects: the occurrence of an induction current in a closed loop–coil when the magnetic flux changes. The model of explanation formed in this way acts as a mental

experiment performed on a system of abstract objects. This model uses the typical features of a demonstration and virtual experiment in the classroom while working with a textbook and computer models.

Table 3.

Tasks of theoretical explanation

Job classification	**Task example**
Tasks for the application of empirical schemes	Determine the signs of the poles of an electric battery that does not have their designations. You have the following equipment at your disposal: a lamp on a stand, a piece of wire, a compass, an electric battery – a direct current source. Develop a research plan, make explanatory drawings and write down your project – research in the lesson.
Tasks for the application of primary models of theoretical explanations	There are flashlight designs where a capacitor is used as a current source, which is connected to a wire coil. Inside the coil is a magnet that can move in it. When you shake the flashlight, the magnet moves. If you turn on the flashlight, the bulb connected to the capacitor lights up. What kind of energy transformations take place? What is the effect of a flashlight?
Tasks for the application of models underlying the developed theories	The problem solved by G. Galileo: "The speeds acquired by the same body when moving along equal inclined planes are equal to each other if the heights of these planes are the same ..." Prove the correctness of this statement. Under what condition is it fair?

The creative tasks of the third group are tasks whose model schemes lie at the foundation of the developed theories. An example of the task of this group is the task of the heading of the textbook "From the history of physics": a problem solved by G. Galileo.

The scheme for explaining the result of the study of this task lies in the foundations of Newtonian mechanics. It is built like a model. The components of this model are abstract objects – force, energy, material point, an isolated system of bodies, as well as the law of conservation of energy. The model summarizes the types of training actions for moving bodies along an inclined plane.

Means of motivation by the content and process of learning activity belong to the fourth type of course content. The classification of means of motivation is based on the idea of the products of educational activity: the development of scientific knowledge and methods of scientific knowledge. The structure and content of the educational material, which encourage students to strive to learn new facts, can serve as a means of motivation. So, in the textbooks, substantive lines are highlighted on: the history of physics and technology; familiarization with technical objects; design and assembly of laboratory facilities; performing frontal and home laboratory work; the use of information tools, including computer support.

For students with an increased cognitive need for textbooks, an approximate topic of educational projects is given. So, in the ninth grade physics course, project topics are grouped into the following groups: from the history of the development of physics, experiment and

modeling are the main methods for studying nature; practical applications of physical knowledge.

The textbooks present material that is aimed at the formation of an emotional–valuable attitude to nature and to oneself, and to each other. For example, in the seventh grade physics course, a theoretical justification is given for an important rule of behavior on the roads for a person – why it is impossible to cross the road in front of fast moving vehicles. In the eighth grade course, students are introduced to precautions when working with electrical appliances and protection measures against electrical network overloads.

The examples show that the activity of mastering the content of physics can be considered as a whole as a polymotivated activity. The motives inherent in the educational activities in physics are related to the content that encourages the desire to master the scientific content and methods of cognition, which means theoretically explaining the physical phenomena occurring in the macro–, micro– and mega–world.

3. Conclusion. The very process of cognition of concepts, laws and theories can also become the leading motive of activity. Performing laboratory research, getting acquainted with fragments of the works of the classics of physics, discussing modern achievements in science and technology, discussing and evaluating the problems of project work, using didactic games is an important means of motivating the learning process.

Thus, the content of a physics course is a systemic concept that includes certain types that implement the relationship between scientific knowledge and methods of cognition. Content types represent scientific knowledge and methods of cognition; means that convey the experience of applying knowledge in familiar situations and in educational creative activities; ways of motivation by the content and process of educational activity. Each type of physics course content reflects the relationship between scientific knowledge and methods of cognition.

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