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A CULTUROLOGICAL APPROACH TO THE FORMATION OF EDUCATIONAL MATERIAL IN PHYSICAL EDUCATION

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Abstract

One of the goals of physics education at a university is the formation of a culture of intellectual activity as an epistemological aspect of culture. To achieve it, the content of a physics course at the level of an academic subject is proposed to be formed based on a didactic unit that determines the technology of constructing the content of education based on a culturological approach: the selection of educational material and its structuring. The paper introduces the concept and proposes the structure of a complex didactic unit of the content of physics education at a university, containing components of three levels of generalization: philosophical and fundamental physical ideas, methods of description, fundamental physical theories. The agreement between these components is determined by a system of methodological principles, which includes a system of fundamental physical principles and a system of general scientific methodological principles of cognition. The advantage of the proposed didactic unit over other tools for systematizing and structuring educational material in physics is that it is part of a general multilevel systemic approach to the formation of the content of physics education. The proposed approach determines the factors of selection of educational material, theoretical and methodological foundations for creating the structure of a subject of study and, accordingly, approaches to the presentation of the material. The paper presents a fragment of the theoretical part of this study.

Keywords: Cultural approach, course content, didactic unit, methodological principles, physical education

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1. Introduction

The culturological approach to the formation of the content of physics education involves the determination of specific goals of teaching physics, the development of the content of physics education, an assessment of the learning outcome in the context of human development, mastering the foundations of culture (Galili, 2019; Galili et al., 2019; Kaluzeviciute, 2021; Matthews, 2020; Seroglou et al., 2018; Stepin, 2016).

The essence of the modern culturological approach to the formation of physics education is recognizing the need to proceed from the interpretation of physics not only as a scientific field but also as an element of human culture and the development of human thinking (Galili, 2018; Henson, 2005; Losee, 2001; Syazwani et al., 2018).

The culturological approach is the result of the logical development of two previous approaches to the formation of the content of education: knowledge and activity. However, the culturological content of education cannot be built by mechanically adding activity and cultural components to the knowledge content of education. The process of transition to new content of education affects all levels of its formation (Burkova, et al., 2021; Colin & Viennot, 2001; Yamalidou, 2021). In the scientific research literature, these issues are solved about individual levels of formation of the content of education, and it is not possible to combine them into an integral system (Cheong, 2016; Colin, 2001; Galili et al., 2019; Kaluzeviciute, 2021; Koponen & Pehkonen, 2010; Stepin, 2016).

2. Problem Statement

In our work, we tried to eliminate this shortcoming and present an integral (covering all five levels of education formation) concept of a culturological approach to the formation of the content of physics education. An element of this concept is presented in this work.

3. Research Questions

The content of education is designed at two levels (the second and third levels of the formation of the content out of five): the level of educational material and the level of the academic subject. At the level of the academic subject, it is proposed to use the complex didactic unit developed by us as a criterion for the selection and systematization of material, which is proposed for discussion in this work. A didactic unit is understood as a structural element of content that is holistic in its semantic meaning, which performs a specific function in realizing the set goals in mastering a subject. We tried to reveal the complex nature of the didactic unit by analysing not only its structure but also the connections between its components.

The didactic unit is a very important link in the content formation system – on its basis, at the next level (the level of educational material), the core idea of the course is highlighted, around which the educational material is grouped, implemented at the level of the learning process.

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4. Purpose of the Study

The initial stage of the research was aimed at determining the didactic foundations for the implementation of the culturological approach to the formation of content at the projected level. On this basis, it was planned to develop methodological support for the cultural orientation of the implemented content of the physics course. The next stage of the study aimed to develop a didactic unit.

5. Research Methods

The first task was to reveal the essence of the culturological approach and study the main problems of its implementation in the content of physics at the university. Three such problems have been highlighted. The first is related to the need to develop a competency-based concept of physics education. As a possible solution to the problem, a model was developed, the description of which is beyond the scope of the topic of the paper. The second problem was the need to determine the goals and objectives of the content of education in terms of culture. In this regard, the formulation of the goal of physics education, given above, was proposed and substantiated. Here it was necessary to offer the means to achieve it.

The third problem was to bridge the gap between general and specific goals of education and approaches to the formation of its content. We have concretized this problem into the task of establishing continuity between the fundamental factors in the formation of content at the level of educational material (the principle of scientific character) and the academic subject (the principle of generalization). As part of solving this problem, the connections between the principles of scientific character and generalization were revealed and, as a result, the means of their implementation were substantiated: the didactic unit and the core idea of the course. Since the didactic unit serves as a criterion for highlighting the core idea of the course, the target "load" in terms of the formation of a culture of intellectual activity (the second problem) should have been borne by it.

Thus, the factors and criteria for the selection and systematization of educational material at the levels of the projected education were identified (Figure 1). The results of the stage are presented below.

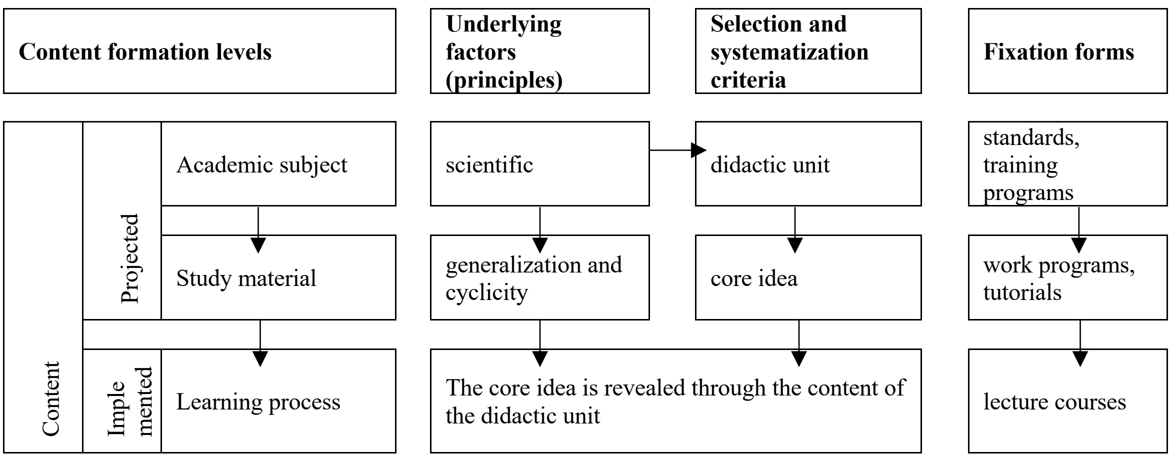

Figure 1. Factors and criteria for the selection and systematization of educational material in the procedure for forming the content of a physics course

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6. Findings

The analysis of various approaches to determining the foundations of the selection and structuring of educational material, methodological approaches to disclosing its content in the learning process was carried out based on the idea that a didactic unit should reflect not only the element of the knowledge system itself but also the process corresponding to its knowledge. The following approaches were highlighted:

- A dynamic model of physical cognition, including the fundamental physical theory, its empirical basis, the original philosophical idea and the corresponding picture of the world;
- Theory and fundamental physical idea;
- Theory and fundamental physical principle;

As a didactic unit, a certain complex meaningful object was used in all cases. The element of least degree of generality in such a complex object is theory. The presentation of a physical theory in a school physics course is possible only at the factual level. Therefore, to clarify its worldview content and connection with modern physics, it becomes necessary to introduce into the didactic unit such elements as fundamental physical ideas, philosophical ideas, fundamental physical principles. The physical picture of the world, in our opinion, cannot fulfil the role of a didactic unit, since the concept of it can be formed only as a result of studying the totality of physical theories related to different physical disciplines. The physical picture of the world serves as an Explanation of the material physical world as a whole, physical theories are a means of describing and explaining its certain areas. Thus, the enlargement of such a didactic unit as a theory inevitably leads to a change in its character to a complex one.

In our opinion, the issue of enlarging the didactic unit of the content of a physics course is most relevant for universities. The content of higher natural science education, adequate to modern requirements, is the basis for the formation, first of all, of a methodological culture. Accordingly, the generalization and systematization of knowledge in higher education should be carried out at the methodological level.

Every physical theory consists of two complementary parts. One part is the equations of the theory, which establish the relationship between mathematical symbols. The other part is the connection of these symbols with the physical world. Without the first, “there is no theory at all”. Without the second part, “the theory is illusory, empty”. When creating each theory, the problems of developing its methodological apparatus arose: interpretation, comprehension, establishing a link between the structural components of the theory and physical knowledge as a whole. The structural components of the science of physics form a certain hierarchy: concepts, laws, theories, fundamental physical ideas, the physical picture of the world. The inclusion in the didactic unit of the elements of physical knowledge, standing above the theory (the degree of generalization of which is higher than the theory), can be carried out in two ways. They are either included in the structure of the theory as its characteristics or together with the theory form a complex didactic unit, being at their level above the theory. We chose the second option since we believe that it creates the basis for the formation of students' ability to determine and designate the levels of systematization of knowledge – one of the fundamental methodological skills.

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In addition, with such a construction of the didactic unit, its "upper" components, firstly, are the principles of the analysis of the worldview content of knowledge, and secondly, they allow solving the problem of reflecting the logical scheme of presentation and analysis of various types of knowledge.

We considered it expedient to single out and designate three levels in the structure of the didactic unit: theories, methods of description and measurement, fundamental physical and philosophical ideas. It should be noted that in the methodology of physics, the levels of methods and principles of description as structural components of science are not distinguished. These concepts were introduced by N. Bohr. By the principles of description, he meant, in essence, the most general logical and epistemological prerequisites for describing and explaining phenomena (i.e. fundamental philosophical and fundamental physical ideas. By the way of description, he meant a fundamental physical theory acting as a tool for cognition of a certain area of physical phenomena. That is, classical mechanics, statistical physics, special and general relativity, quantum field theory serve as a description method in the sense that they are a method for particular theories. In this meaning, the principles of description are referred to the level of ideas, and the methods of description – to the level of theories. When it comes to three historically relative ways of describing: classical, relativistic and quantum, it is about the methodological conceptual structure of the fundamental physical theory. This is already knowledge about knowledge, which describes the approach to the construction of a theory. In this sense, methods of description should, in our opinion, occupy a separate level in the hierarchy of structural components of physics.

The structure of the complex didactic unit, developed by us for the formation of the content of the physics course at the level of the academic subject, is schematically shown in Figure 2.

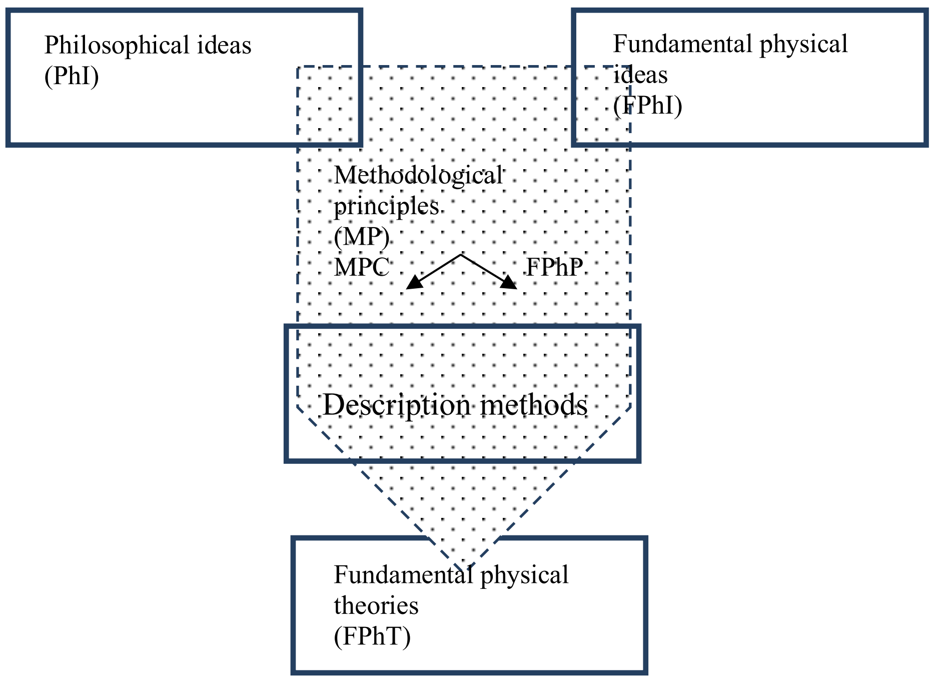

Figure 2. Didactic unit of the physics course

The diagram shows the components of three levels of generalization: ideas (fundamental physical (FPhI) and philosophical (PhI), methods of description, fundamental physical theories (FPhT). The system of general scientific methodological principles (MP), which includes a system of methodological

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principles with an epistemological foundation (principles of cognition (MPC) and a system of methodological principles with an ontological foundation (fundamental physical principles (FPhP), coordinates the components of these levels. The first system (MPC) includes the following principles of scientific knowledge: the universality of materialistic dialectics, the unity of historical and logical, formalization, tolerance, observability, explanation, continuity, in the second (FPhP) – the principles of the unity of the physical picture of the world, conservation, symmetry, complementarity, relativity, causality, correspondence.

Such a didactic unit, in our opinion, lays the foundations for the content of a physics course that meets all the requirements of the didactic principle of scientific character and related principles of generalization and cyclicity. Modern physical knowledge is revealed through the content of fundamental theories and ideas. Methods and patterns of scientific knowledge – through the methodological principles and structure of the didactic unit.

Let's consider the relationship between the individual elements of a complex didactic unit about optics. Fundamental physical principles play a system-forming role; therefore, we will reveal their connection with fundamental physical ideas, methods of description and fundamental physical theories.

6.1.Relationship between FPhP and FPhI

FPhIs were considered in the works of philosophers B.G. Kuznetsov, B.M. Kedrov, V.S. Gotta, J.M. Gelfer and others. In the works of physicists – methodologists V.G. Razumovsky, A.A. Pinsky, E.S. Kamenetsky.

There is no consensus on the separation of FPhI. We formed the FPhI system based on the principle of generation and were guided by the provision that each idea should represent the development and generalization of a specific methodological principle in that aspect that can be disclosed based on optics (strictly speaking, we are talking about the philosophical content of the FPhP).

We connected the idea of preserving the most important characteristics of matter with the principle of conservation, with the principle of complementarity – the idea of the unity of the properties of matter (discontinuity and continuity), with the principle of symmetry – the idea of symmetry of wave and corpuscular formalism, with the principle of relativity – the idea of relativity of the process of physical cognition, with the principle of correspondence – the idea of transition from relative truths to absolute, with the principle of causality – the idea of physical determinism: causality and regularity of natural phenomena (Table 1).

Table 1. Links between the structural elements of a didactic unit: methodological principles, fundamental physical ideas and philosophical ideas

Philosophical idea	**Unity of opposites (harmony, simplicity)**		**Negation of negation**	**Non-creation and indestructibility of matter**	**Cognizability of the material world and the objective nature of knowledge**	
FPhI	The unity of the properties of matter (discontinuity and continuity)	Unity of additional ways of describing	Dialectics of transition from relative truths to absolute truths	Preservation of the most important characteristics of matter Invariance of the	The relativity of the process of physical cognition	Physical determinism: causality and regularity of natural phenomena

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				structure of physical knowledge		
FPhP	Complementarities (the presence of opposite, mutually exclusive properties of objects)	Symmetries (asymmetry of object properties, formal symmetry of wave and corpuscular description)	Compliance (the criterion for the truth of a new theory is its passage to the limit to the original one)	Conservation (conservation of the amount of matter, momentum, angular momentum, energy; constants)	Relativity (to the means of observation)	Causality (classical, relativistic, quantum)
MPC	Tolerance	Formalization	Continuity	Unity of historical and logical	Observability	Explanations

The highest level of generalization of physical knowledge is philosophical. For the methodological analysis of physical knowledge, the following philosophical ideas and principles are used:

- the material unity of the world (the primacy of matter and the secondary nature of consciousness. The unity and diversity of forms and types of the existence of matter. The non-creation and indestructibility of matter. The inexhaustibility of matter);

- development (connection of matter with motion. Movement and development in nature and society. Development as the transition of quantitative changes into qualitative ones. Development as a struggle of opposites);

- universal connection (interrelation of forms of motion of matter. Nature as a whole);

- interactions (interaction at various structural levels of the organization of matter).

The ten general philosophical laws and categories are reflected in the structure of the scientific picture of the world (SPW), which can be considered as philosophical ideas:

- the unity of the picture of the world (PW) – a reflection of the materiality of the surrounding reality;

- diversity, interconnection and unity of various forms and types of matter; space and time are the main forms of the existence of matter; the interaction is a universal form of connection between bodies and phenomena, the source of all forms of motion of matter; causality and regularity of phenomena; nature as a form of universal connection and determinism; non-creation and indestructibility of matter and motion; the cognizability of the material world and the objective nature of cognition; the primacy of matter about consciousness; inexhaustibility of matter and its knowledge.

From our point of view, the relationship between FPhP and philosophical ideas is easier to reveal through the relationship between the last FPhI (Table 1). We generalized the physical ideas of the unity of the properties of matter and the unity of additional methods of description at the philosophical level with the idea of the cognizability of the material world and the objective nature of cognition, the idea of dialectics of transition from relative truths to the absolute –with the idea of negation of the negation, the idea of preserving the most important characteristics of matter – with the idea of the non-creation and indestructibility of matter.

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6.2. Relationship between FPhP and methods of description

Disclosure of the relationship between fundamental physical principles and methods of description involves consideration of the genesis and development of methodological principles based on the concept of evolution of methods of description. Three historically relative ways of description – classical, relativistic and quantum, are the most important characteristics of the corresponding stages of the evolution of the physical picture of the world: mechanical picture of the world (MPW), electrodynamic picture of the world (EDPW), quantum field picture of the world (QFPW). Not being able to analyse the methodological content of the description methods, we will only consider the issue of the specific scientific content of the principles within the framework of different description methods.

The content of the modern quantum-mechanical principle of causality in the classical and relativistic ways of description was interpreted as Laplace's determinism (Table 2).

The idea of correspondence was first expressed by M. Planck in 1906. The principle of the same name was formulated in 1913 by N. Bohr. Thus, the original content of the correspondence principle, formed within the framework of the quantum method of description, is still relevant today: a theory is true if, with a corresponding transition, its laws turn into the old initial theory.

The idea of relativity was formulated by R. Descartes and G. Galilei. In the classical way of description, relativity was identified with Galileo's principle of relativity (the relativity of mechanical motion about the reference system). The relativistic method of description affirms the relativity of description to the reference system not only of motion, but also of space, time, and other physical concepts (Einstein's principle of relativity). The quantum mechanical principle of relativity determines the relativity to the means of observation.

The development of the idea of symmetry, as a property of an object to retain its shape or mutual correspondence under any transformations, can be represented as a chain:

- symmetry concerning transfer in space (homogeneity of space);
- symmetry concerning rotation in space (isotropy of space);
- symmetry concerning transport in time (homogeneity of time);
- symmetry concerning time reversal (T-invariance);
- symmetry concerning specular reflection (P - invariance);
- symmetry concerning charge conjugation (C-invariance);
- symmetry concerning combined parity (CPT - theorem);
- symmetry as a reflection of the dialectic of the interconnection of natural phenomena.

In fundamental physics, symmetries are divided into geometric and internal (discrete symmetry). Transformations corresponding to geometric symmetries contain spatial and temporal shifts, spatial rotations, space-time rotations, mirror reflections of the coordinate axes: three spatial and temporal ones. Symmetry concerning each of these transformations, except the last one, has its conserved quantity: momentum, energy, angular momentum, Lorentzian moment, spatial parity. Symmetry concerning the reflection of the time axis corresponds to the property of reversibility of physical processes.

Transformations that correspond to internal symmetries usually link together different but related particles. So, for example, charge conjugation transforms particles into the corresponding antiparticles,

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isotopic transformations transfer various components of isotopic multiplets into each other, etc. These symmetries correspond to the conservation of charge parity, isotopic spin, colour, etc.

The classical and relativistic methods of description correspond to geometric symmetry (the first five elements of the chain), in the quantum one, internal symmetry is added (the last three elements of the chain).

Preservation of description in a classical way was expressed in the preservation of matter and its characteristics (amount of matter, momentum, angular momentum, energy, electric charge), in a quantum way – in the preservation of the number of matter particles and their characteristics (baryon charge, lepton charge, parity, strangeness). In the quantum method of description, new forms of conservation expression appear in the structure of physical theories–invariance (the principle of unitarity in quantum theory is a modern formulation of the principle of conservation of matter), the principle of invariance of scientific laws is formulated.

The idea of complementarity belongs to N. Bohr and dates back to 1927. The definition of the concept of complementarity, which formed the basis of the principle in its traditional understanding, was formulated by W. Pauli. He called"additional" two classical concepts – and not two ways of describing – if the use of one of them is associated with the exclusion of the use of the other.

The relationship between FPhP and description methods is presented in Table 2.

1)The relationship between FPhP and FPhT is revealed through the connection between FPhP and methods of description.

2)Thus, the relationship between the structural elements of a didactic unit is revealed through the connection of FPhP with philosophical ideas, methods of description, fundamental physical theories.

Table 2. Relationship between fundamental physical principles and methods of description

Description method	FPhP					
	Causality	**Compliance**	**Relativity**	**Symmetries**	**Conservation**	**Complementarities**
Classical	Laplace determinism	***	Galileo's principle of relativity (mechanical, to the frame of reference)	Geometric symmetry of space and time	Preservation of the substance and its characteristics	***
Relativistic	Laplace determinism	***	Einstein-Poincaré's principle of relativity (relativistic to the reference system)	Geometric symmetry of the space-time continuum	Conservation of matter and its characteristics	***
Quantum	Quantum mechanical principle of causality	Compliance principle: The new theory contains the old one as a special case.	Quantum-mechanical principle of relativity (to means of observation)	Internal symmetry; discrete symmetry of the space-time continuum	Invariance (the principle of unitarity in quantum theory) The principle of invariance of scientific laws, equations	Complementarity of mutually exclusive concepts for completeness of description

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7. Conclusion

Formation of the content of physics education based on a culturological approach should be a procedure consisting of the following stages: highlighting the core idea based on a conceptual assessment of the subject content of a complex didactic unit; selection of key questions based on the core idea; defining the structure of the course content based on the core idea and key questions; development of methodological means of a culturological orientation based on the subject content of a complex didactic unit; development of a methodology for presenting individual issues of the course, taking into account the methodological means of a culturological orientation.

The key structural link of the design system for the content of physics education is a complex didactic unit, which includes the following elements: philosophical and fundamental physical ideas, methods of description, fundamental physical theories. The relationships between these elements are determined according to methodological principles with an ontological and epistemological basis.

The next stage of the research is the development based on the proposed concept of the culturological content of the optics course from the projected to the implemented level. This will allow showing, firstly, the fundamental possibility of constructing an integral concept of a culturological approach to the formation of the content of physics education that implements the principle of unity of the didactic and methodological foundations of development, secondly, the possibility of creating an algorithm for the procedure for forming the content of a physics course – from the projected to the implemented level, and thirdly, the possibility of revealing the culturological content of education using the subject itself.

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