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DEVELOPMENT OF INFORMATION-CYBERNETIC THINKING IN STUDENTS OF PEDAGOGICAL UNIVERSITIES

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Abstract: *The article deals with the actual problem of the development of information-cybernetic (Inf.-Cyb.) thinking in students of pedagogical specialties. As a result of the analysis of scientific and educational literature: 1) the content of the "Inf.-Cyb. thinking" concept is defined and the necessity of its use in the discussion of studying of computer science and cybernetics is justified; 2) the methodical system for the formation of Inf.-Cyb. thinking, containing target, content, procedural and diagnostic components is proposed; 3) various types of educational tasks that help to form Inf.-Cyb. thinking in students of pedagogical specialties are considered. Inf.-Cyb. thinking should be understood as: 1) the ability to explain the functioning of various information and cybernetic systems by identifying the main blocks, information flows and control chains; 2) the ability to solve typical problems in computer science and cybernetics; 3) algorithmic thinking, the ability to create algorithms and to program electronic devices; 4) the ability to interact with information and cybernetic systems in order to solve practical problems.*

Keywords: *algorithmization, informatics, world picture, cybernetics, technique, thinking, programming.*

Introduction

There are two aspects of the surrounding world organization: material-energetic and cybernetic-informational; they correspond to the natural science and information-cybernetic picture of the world, which are part of the unified scientific world picture. Development of Inf.-Cyb. picture of the world and corresponding infocybernetic thinking is an important condition for the formation of professional competencies in students of pedagogical specialties. Future teachers of computer science, physics and mathematics should have an information-cybernetic approach when explaining the functioning of complex systems, be able to solve typical problems in computer science, understand algorithms and programs, successfully interact with various electronic devices, Internet resources, etc., and also explain the main provisions of computer science and cybernetics to schoolchildren. The objective of the article is to define the concept of "Inf.-Cyb. thinking", to study its connection with the Inf.-Cyb. world picture and worldview, and the development of the methodology for the infocybernetic thinking formation when teaching students of pedagogical universities. The methodological basis of the research is the works by V.P. Bespalko [1], V.I. Zagvyazinsky [2] (pedagogy); V.E. Lepsky [3], V.P. Melnikov and A.G. Skhirtladze [4], A.V. Chugunov [5], D.A. Novikov [6], N. Wiener [7] (cybernetics); Yu.V. Borodaki and Yu.G. Lobodinsky [8], V.K. Dushin [9] (computer science); M.B. Ignatiev [10], V.P. Soloviev [11] (philosophy and cybernetics); M.P. Lapchik [12], I.V. Robert [13] (methodology of teaching computer science). The theoretical research methods used are: analysis and synthesis, induction and deduction, qualitative modeling, logical reasoning.

1. The concept of "information-cybernetic thinking"

In psychology, thinking is called a form of the objective reality mental reflection which allows a person to discuss objects and obtain such knowledge about their properties, connections and relationships with other objects that cannot be established with the help of the senses. This process is inextricably linked with speech. It occurs as a result of mental operations (comparison, analysis, synthesis, concretization, generalization) during which a person comprehends the essence of the being researched [2]. Psychologists distinguish the following main types of thinking: visualeffective, visual-figurative and verbal-logical. Methodists also use the following concepts: physical, mathematical, historical, spatial and other types of thinking. The content analysis of the information-cybernetic disciplines, studying of scientific and methodological literature [12, 13] has made it possible to determine Inf.-Cyb. thinking as a cognitive process of establishing connections between parts of information and cybernetic systems, a special way of explaining their functioning, which provides for: 1) picking out the main blocks, information flows and control chains; 2) logical reduction of the analyzed processes to the main propositions of informatics and cybernetics; 3) creation of algorithms and computer programs; 4) student interaction with information and cybernetic systems in order to solve practical problems. In these cases, conclusions and judgments use the concepts: "information", "entropy", "signal", "encoder", "communication channel", "control", "sensor", "feedback", "black box", "robot", "homeostasis", etc.

Infocybernetic thinking develops simultaneously with the formation of Inf.-Cyb. world picture (that is, Inf.-Cyb. component of the scientific world picture) – a generalized model of the surrounding world which includes ideas about: 1) information, methods of its measurement and general principles of control; 2) algorithmization and programming; 3) flowing of information processes and functioning of cybernetic systems of various nature. We will assume that the student has formed an Inf.-Cib. picture of the world and the corresponding thinking, if explaining the surrounding phenomena he/she is able: 1) to identify and explain information processes using the basic concepts and propositions of informatics; 2) to use knowledge about methods of encoding numerical, textual, graphic, video and audio information; 3) to create algorithms and computer programs; 4) to disscuss the physical nature of information processes; 5) to explain the cybernetic systems operation, picking out the main blocks, direct connections and feedback, using the cybernetics principles; 6) to successfully interact with information and cybernetic systems to solve practical problems.

Basing on Inf.-Cyb. world pictures, infocybernetic thinking, as well as the systems of values and beliefs that arise as a result of students' interaction with various information and cybernetic systems and discussion of their functioning with other people, they form Inf.-Cyb. worldview. This component of the scientific worldview includes an objective component (Inf.-Cyb. world picture, as a subject basis) and a subjective component (system of values and beliefs, that is, emotionally colored knowledge). All this proves the concept “Inf.-Cyb. thinking” usefulness and the expediency of its use in didactics.

2. The formation method of Inf.-Cyb. thinking

The study of scientific and educational-methodical literature [4, 5, 9] has made it possible to establish that Inf.-Cyb. thinking consists of three components: 1) infological thinking, which consists in a logical explanation of the information systems functioning, methods of encoding various types of information and calculating the information amount in a message; 2) algorithmic thinking as a set of mental actions leading to the creation of an algorithm or computer program that solves a given problem; 3) the ability to apply infocybernetic approach for the analysis and synthesis of information-cybernetic systems. The proposed methodological system for the development of Inf.-Cyb. thinking is created on the basis of well-known approaches to teaching informatics and cybernetics [12, 13]. It includes target, content, procedural and diagnostic components:

1. The target component contains: 1.1. Objective: to form the Inf.-Cyb. thinking, consisting in the ability to explain processes taking place around, applying the basic concepts and propositions of informatics and cybernetics; 1.2. Tasks: to develop in students: 1) the ability to solve typical problems in computer science and cybernetics; 2) the ability to create algorithms and to program electronic devices; 3) the ability to analyze information-cybernetic systems, using the info-cybernetic approach; 4) the ability to interact with information and cybernetic systems.

2. The content component of the methodological system includes the following types of training tasks, the fulfillment of which leads to formation of the appropriate intellectual skills:

A. Tasks for the infological thinking development requiring: 1) calculating the entropy of experience and the amount of information in a message; 2) knowing of various number systems; 3) encoding of digital, text, graphic and other information; 4) logical justifying and using of the Shannon, Kotel'nikov theorems, the Shannon-Hartley formula for connection channel and other provisions of computer science; 5) encoding and decoding messages; 6) creating prefix codes; 7) the representing of numbers in another number system, performing logical operations, etc.

B. Tasks for the algorithmic thinking development requiring: 1) analyzing of algorithm or program, predicting of the their execution result; 2) creating of algorithm that solves a certain problem; 3) writing of computer programs that solve equations, model various systems, calculate derivatives and integrals, build graphs, etc.; 4) applying of a normal Markov substitution system; 5) programming of Post and Turing machines; 6) analyzing of deterministic and probabilistic automata; 7) creating of text, audio, photo and video files, presentations; 8) working in spreadsheets and databases; 9) using a search engine, an electronic translator, a dictionary; 10) interacting with e-mail, social networks, other Internet resources, etc.; 11) using of cell phone, connecting peripheral devices to a computer, programming robots, installing software, etc.

C. Tasks for developing the ability to apply the infocybernetic approach requiring: 1) mastering the system approach; 2) applying the basic propositions of computer science and cybernetics when discussing the principle of various information and cybernetic systems operation; 3) knowing the principle of operation of logic elements, triggers, coordinated operation of the processor, RAM, ROM, external memory, input-output devices, computer, radio communication systems, television; 4) "inventing" cybernetic systems with given properties that solve a specific problem; 5) knowing logic elements and combinational schemes.

3. The procedural component consists of the forms, means and methods of organizing the educational process, as well as the applied methodology: 3.1. Forms: multimedia lecture, seminar, laboratory practice in the electronics laboratory and classes in the computer laboratory. 3.2. Means: a lecture room, an electronics laboratory, a computer classroom, teaching materials, software, equipment for laboratory work, a multimedia projector with a screen and an interactive board. 3.3. Methods: verbal, visual, practical, problem-search, multimedia presentation of educational material, oral and written questioning, guided discoveries. 3.4. Methodology: 1) modular training; 2) problem and developmental learning; 3) logical-informational approach; 4) activity approach; 5) the use of science-intensive educational technologies; 6) deepening of interdisciplinary connections between informatics, cybernetics, physics, technology, biology and social sciences; 7) intensification of mental activity, the cognitive interest formation.

4. Diagnostic component: Learning outcomes diagnostics is carried out with the method of oral questioning and testing, during which the formation of the Inf.-Cyb. thinking components is checked (that is, the ability to perform the tasks listed above).

An teacher's important professional quality is the ability to express their thoughts, reason and explain educational material. Therefore, the formation of the teacher's competencies presupposes the development of students' oral and written speech, which is the material result of mental activity, developing simultaneously with thinking. Students should learn to orally explain new material, solve a problem, analyze the control systems operation, using scientific terminology, logical reasoning, referring to the most important ideas of computer science and cybernetics.

3. Content component of the methodological system

Thinking in a specific subject area is formed in the process of: 1) studying the corresponding system of reasoning and logical evidence; 2) the performance of intellectual tasks that require reasoning; 3) oral discussion of certain issues of the relevant discipline, writing essays and other works. In the pedagogical university students' Inf.-Cyb. thinking is developed primarily in the study

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of information disciplines: "Computer Science", "Programming", "Networks and Internet Technologies", "Artificial Intelligence", "Robotics", "Theoretical Foundations of Informatics", "Information Systems", "Computer Architecture", etc. The analysis of specific control systems should use scientific terminology and include discussion of the fundamental cybernetics laws.

1. The formation of infological thinking. An important professional quality of future computer science teachers is the ability to logically explain the operation principle of various information systems, understand the methods of encoding text, numeric, graphic, audio and video information, calculate the entropy of experience and the information amount in a message. At the lectures, students get acquainted with mathematical models of information processes, methods of data processing (collection, filtering, sorting, archiving, transformation, protection, transmission), learn to perform arithmetic operations with binary numbers, logical operations, solve various information-search, logical-analytical and search-optimization problems related to the transformation of information, etc. To develop the mechanisms of thinking, it is not enough to get acquainted with the well–known arguments about the functioning of complex systems. It is necessary to independently solve the corresponding intellectual tasks. The university course in computer science contains a lot of educational tasks on the topics: "Entropy and the information amount", "Coding and Decoding of Messages", "Numeral Systems", "Coding of Numbers", "Shannon-Fano Prefix Code", "Huffman Code", "Neural Networks", "Logic Gates and Functions", "Combination Circuits", etc. In the process of solving them, students actively use the concepts of "entropy", "informativeness of the message", "source productivity", "communication channel capacity", "average length" and "relative code redundancy", "uniform code", "prefix code", "code distance", "floating-point format", "additional number code", etc. Discussion of these issues contributes to the development of the student's infological thinking.

2. Formation of algorithmic thinking. Another component of Inf.-Cyb. thinking is algorithmic thinking, that is, a set of intellectual actions and techniques, as a result of which an algorithm for solving a problem is created. These include: dividing the analyzed problem into blocks (subtasks), solving them with subsequent detailing and reducing to a certain operations sequence, the implementation of which leads to the solution of the original problem. Algorithmic thinking is distinguished by formality, clarity and consistency, the ability to move from a vague idea to an algorithm - a discrete sequence of elementary operations that transform information or matter, the implementation of which allows you to achieve the goal. This kind of thinking develops in the process of discussing various algorithms and programming complex cybernetic devices (computer, robot, Arduino processor, cell phone, etc.).

To form algorithmic thinking, students perform the following tasks: 1) they analyze working of a known algorithm or program, predicting the result (numbers, symbols, graphic images); 2) they independently create an algorithm that solves a specific problem; 3) they write computer programs in *ABCPascal*, *Lazarus* and other environments that solve equations, model various systems, calculate derivatives and integrals, plot function graphs, etc.; 4) they work with the normal Markov substitution system; 5) they perform tasks for programming Post and Turing machines; 6) they analyze the work of deterministic and probabilistic automata; 7) they create presentations, text, audio, photo and video files with the help of application programs; 8) they work in spreadsheets and databases; 9) they use a search engine, electronic translator, dictionary; 10) they interact with e-mail, social networks, other Internet resources; 11) they work with a cell phone, connect peripherals to a computer, program robots, etc. This leads to deepening of the concept "algorithm" and the algorithmic culture development, skills formation to interact with information and cybernetic systems to solve practical problems.

Algorithmic thinking develops in the process of creating computer programs. A computer is a complex cybernetic device, so programming it is an interesting task. Of particular interest is the work with computer programs that simulate various information or cybernetic processes and systems. The following questions can be studied with the method of computer simulation [14]: 1)

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coding, decoding and encryption of messages; 2) functioning of deterministic and probabilistic automata; 3) checking the algorithmic solvability of problems using Post and Turing machines, normal Markov algorithms; 4) operation of the speed controller and other control systems; 5) the functioning of the Ashby homeostat, etc. Working with such computer models, students learn algorithmization and programming, assimilate the functioning features of the simulated cybernetic system. All this contributes to the development of the ability to use a computer to solve various problems, deepens interdisciplinary connections between mathematics, physics and computer science.

3. Formation of the ability to use the infocybernetic approach. Application of Inf.-Cyb. approach to a certain research object involves its system analysis, the identification of control and controlled subsystems, information flows, control circuits and feedback, the explanation of its functioning with the help of the basic informatics and cybernetics ideas. To develop this ability, it is necessary to acquaint students with the system approach and use it several times in the analysis of various information and cybernetic systems. The system approach essence is that any object is considered as a system, that is, a set of interrelated elements (subsystems) that has an output (goal), input (resources, control actions), connection with the external environment and feedback. This uses: 1) the integrity principle; 2) the hierarchy principle; 3) the structuring principle; 4) the principle of multiplicity description; 5) the systemicity principle. The monograph [5, p. 37] lists eight aspects of the system approach. It follows from them that for the analysis of the system S it is necessary: 1) to identify the elements that make up S; 2) to establish connections between elements, represent the internal structure of the system S; 3) to determine the functions for which S is intended; 4) to establish the goals and subgoals of the system S; 5) to identify the resources required to solve a particular problem by the system S; 6) to determine the properties of S, ensuring its integrity and singularity; 7) to identify external relations S with the environment (other systems); 8) to study the conditions for the emergence of S, its past, present and possible development prospects.

The formation of the ability to use infocybernetic approach can be carried out while studying various disciplines. Students study: 1) functioning of the Watt speed controller, temperature controller, computer, satellite television system, neural network machine learning system, coding and decoding systems, various types of robots (courses "Computer Science" and "Cybernetics"); 2) the principle of operation of logic elements, triggers, coordinated operation of the processor, RAM, ROM, external memory, input-output devices, computer, radio communication systems, television (course "Electronics"); 3) basic ideas of biological cybernetics, biological laws of transmission of genetic information, the role of DNA in the subsequent development of the organism (course "Natural science world picture"); 4) the most important provisions of bioinformatics, medical and psychological cybernetics, learn to use them to explain the work of the respiratory, cardiovascular, digestive, nervous systems (courses "Physiology", "Psychology"); 5) the theory of personality and the psyche, according to which a person is a self-regulating information system that develops due to the implementation of information needs (course "Psychology"); 6) ideas of pedagogical cybernetics, the direct and feedback relationships that arise in the system "teacher-students" [14, pp. 553-574], possibilities of the programmed learning and using of automated learning systems (course "Pedagogy"); 7) methods of managing separate economy areas and society as a whole, feedback arising from scientific and technological progress, economic reforms, wars, epidemics (course "History", "Sociology", "Social studies").

For the development of thinking mechanisms it is not enough to get acquainted with the well-known reasoning about functioning of complex systems – it is necessary to independently perform corresponding intellectual tasks. Students can be offered training tasks for the “invention” of information-cybernetic systems designed to solve certain problems. For example, it is necessary to develop a missile flight stabilization system consisting of a gyroscope with rotation sensors, an accelerometer, an electronic control device and actuators that turn the ailerons and change the fuel supply to the engine. The fulfillment of these and other educational tasks should be accompanied with their discussion using the appropriate terminology, logical reasoning based on the important

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propositions of computer science and cybernetics. At this any purposeful behavior of the analyzed system is considered as a result of control; methods of coding information, adaptation of complex systems, homeostasis, etc. are discussed.

Conclusions

The novelty of the work is as follows: 1) the content of the concept "information-cybernetic thinking" is determined and the expediency of its use in didactics is shown; 2) a methodical system for the formation of Inf.-Cyb thinking is proposed; 3) various aspects of the formation of students' algorithmic thinking and the ability to use the infocybernetic approach are analyzed. It is shown that Inf.-Cyb. thinking is: 1) the ability to explain the functioning of various information-cybernetic systems by identifying the main blocks, information flows and control chains; 2) the ability to solve typical problems on the computer science and cybernetics; 3) algorithmic thinking, the ability to create algorithms and to program electronic devices; 4) the ability to interact with information and cybernetic systems in order to solve practical problems. Its formation implies performing educational tasks for: 1) theoretical study and application of the provisions that make up the core of Inf.-Cyb. world pictures; 2) solving professionally oriented problems on computer science and cybernetics; 3) verbal, mathematical and computer modeling of the studied systems; 4) algorithmization and programming of various devices; 5) "invention" of cybernetic systems with given properties; 6) the experimental study of technical systems.

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