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ON FORMATION OF THE INFORMATION-CYBERNETIC WORLD PICTURE AT PEDAGOGICAL UNIVERSITY

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Abstract: *The article considers the creation problem of the information-cybernetic world picture (Inf.-Cyb. PW) in the pedagogical specialities students' consciousness, which is an important element of the general scientific worldview. It includes a set of theories that allow us to understand the information processes essence and the cybernetic systems functioning, the most important principles and ideas of computer science, cybernetics, artificial intelligence and robotics. Formation of the educational version of Inf.-Cyb. PW in the students' minds is a necessary condition for the future teachers education. The logical-semantic model of Inf.-Cyb. PW is proposed, which has the form of multipath graph whose vertices correspond to the most important concepts, ideas and theories. Various approaches to the concept "information", as well as the relationship between the concepts "message entropy" and "entropy of a physical system" are discussed. The study of complex Markov algorithms and proof of the problem algorithmic solvability using a computer is considered. The article analyzes the features of the development of information and cybernetic thinking among the pedagogical universities students, when studying the disciplines of the information cycle, certain issues of electronics, robotics, biology, physiology, psychology and pedagogy, creating closed and open opto-mechanical control circuits based on a personal computer.*
Keywords: *didactics, computer science, worldview, cybernetics, methodology, modeling.*

Introduction

The professional competences development of computer science, physics and mathematics teachers assumes the formation of the information-cybernetic world picture for the pedagogical specialties students (Inf.- Cyb. PW) as an important component of the unified scientific picture of the world. The information picture of the world appeared in the middle of the XX century when analyzing technical, biological, social systems and information processes of various nature from the positions of information and cybernetic approach [1]. Inf.- Cyb. PW is closely related to the material-energy (or natural-science) world picture and the technical world picture.

The article purpose is to define the concept of educational information-cybernetic world picture, to establish its content and discuss the features of its formation in pedagogical universities students' mind. The methodological basis of the research is the works by B.M. Velichkovsky [2], I.A. Zimnaya [3], P.M. Erdniev and B.P. Erdniev [4], V.E. Steinberg [5], T.V. Minkovich [6] (didactics), V.V. Gubarev [7], M.P. Lapchik, M.I. Rigulina and I.G. Semakin [8], K.Ju. Polyakov and E.A. Eremin [9], I.V. Robert [10], B.V. Sobol, A.B. Galin, Yu.V. Panov, E.V. Rashidova and N.N. Sadovoj [11] (methods of teaching informatics), L. V. Rozanova [12], D.A. Novikov [13], N. Wiener [14] (cybernetics), N.A. Kuznetsov, O. E. Baksansky and N. A. Grechishkina [15], L.V. Moiseeva [16], S.N. Grinchenko [17], O.V. Krasnova and A.A. Krasnov [18] (information and cybernetic approach).

1. Concept of educational information-cybernetic picture of the world

The information-cybernetic picture of the world that exists in the scientists minds (Inf.- Cyb. PW) is part of the unified scientific picture of the world (PW), in which it is included together with the natural science PW, historical, socio-economic and technical PW, forming an integral system. Inf.- Cyb. PW includes a set of theories that allow us to understand the essence of information processes and the functioning of cybernetic systems, the most important principles and ideas of computer science, cybernetics, artificial intelligence (AI), and robotics (Fig. 1). It is related to the

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technical world picture, which includes the laws of the technical objects development and gives the generalized idea of their operation principles. Methodological scientists carry out the adaptation of Inf.- Cyb. PW to the training conditions, getting a simplified education Inf.- Cyb. PW, which is in the minds of the information disciplines teachers. At studying its constituent elements, in the students' minds the individual images of Inf.- Cyb. PW are formed, which are simplified "casts" of scientific Inf.- Cyb. KM, information and cybernetic thinking are developed.

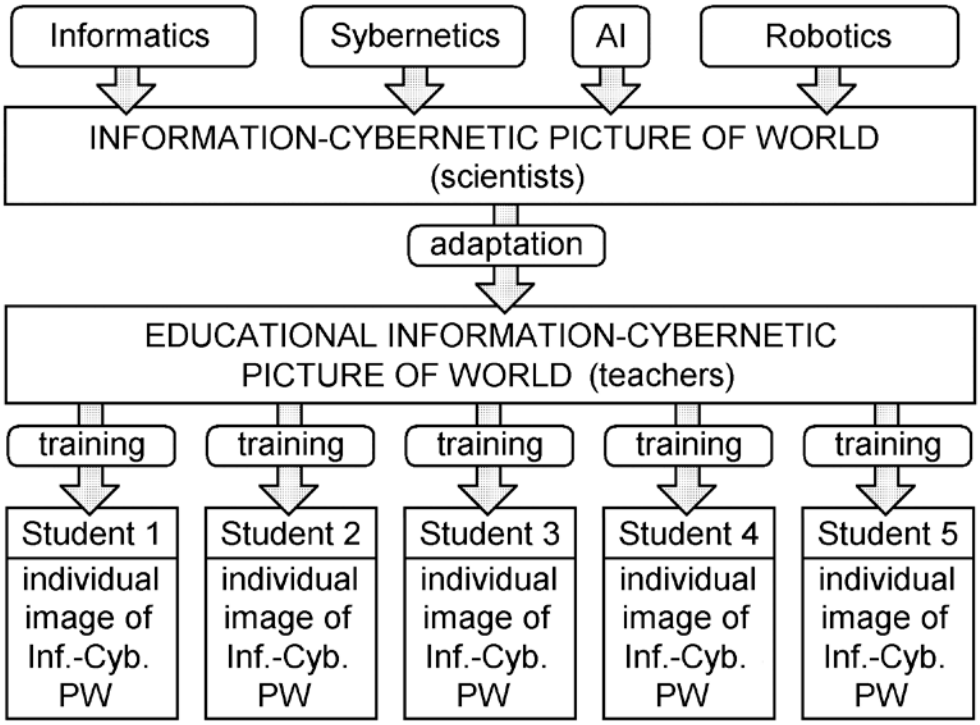

Fig. 1. To the discsussion of information-cybernetic world picture formation in the students' consciousness.

The need to form the educational Inf.- Cyb. PW in the pupils' and students' minds is due to the following. When analyzing technical, biological and social systems, students use the concepts "information", "coding", "throughput", "control", "feedback", etc., discuss various information processes and control chains, which, despite their different nature, obey general laws. To increase the knowledge systemicity, it is necessary to form a holistic view on the functioning of information and cybernetic systems, to study the fundamental principles of information processing, storage and transmission, to establish appropriate intersubject links, and to develop a unified approach to the analysis of information processes of various nature.

In the pedagogical university educational variant of Inf.- Cyb. PW is formed primarily when studying the following disciplines included in the module "Informatics": "Computer Science", "Programming", "Bases of Knowledge", "Fundamentals of robotics", "Operating systems", "Networks and Internet technologies", "Workshop on solving tasks with computer", "Theoretical foundations of computer science", "Information systems", "Computer Architecture", "Computer modeling", "Fundamentals of artificial intelligence". Core of Inf.- Cyb. PW is formed by the fundamental concepts, ideas and principles of information processing and functioning of cybernetic systems, for example: the Hartley-Shannon formula, Shannon's theorems on the transmission of messages over a communication channel, the encoding methods, archiving, encryption, and others. Peripherals of educational Inf.- Cyb. PW includes knowledge about the physical principles of operation and characteristics of devices which are processing information: processor, RAM, encoder, magnetic memory, etc., as well as examples of using the main ideas of computer science and Cybernetics to explain technological, biological and social processes. In addition, Inf.- Cyb.

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PW contains fundamental ideas inherent in any scientific world picture: the principles of causality, observability, correspondence, symmetry, optimality, and prohibition.

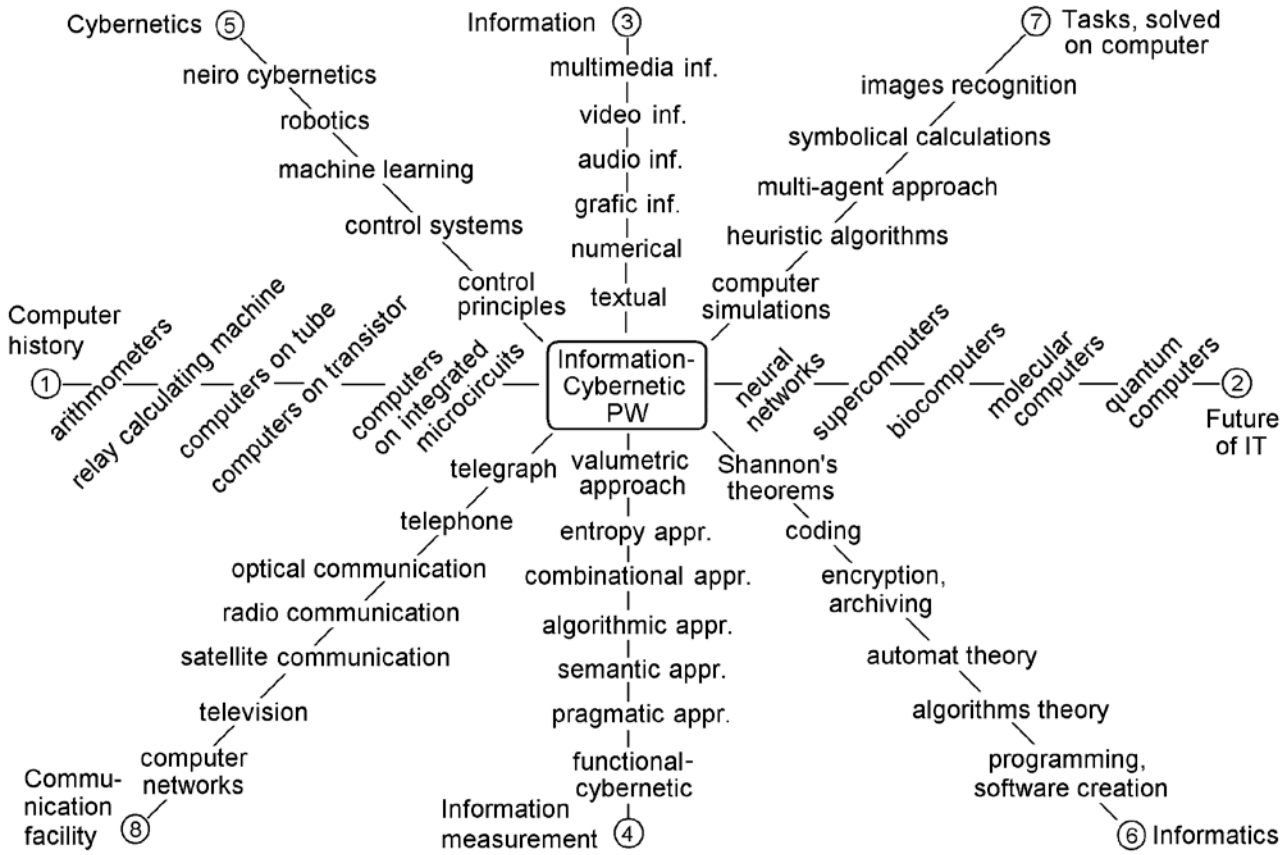

Fig. 2. The logical-semantic model of the information-cybernetic world picture.

To visualize the content of the educational Inf.- Cyb. PW, we will use the logical-semantic modeling (LSM), the founder of which is V. E. Steinberg [4, 5]. This method consists in representing the content of a certain knowledge area using a multipath graph, the vertices of which are concepts or didactic units, and the edges symbolize the connections between them. To create the logical-semantic model, key concepts are written and "power information lines" are identified, around which didactic units are grouped, forming heterogeneous semantic groups [5]. The possible variant of the logical-semantic model of information and cybernetic PW is shown in Fig. 2. In the space of attributes, the main semantic coordinates are highlighted: 1) the past of computer technology; 2) the future of computer technology; 3) the information types; 4) the measuring information methods; 5) the cybernetics issues; 6) the computer science issues; 7) the tasks solved on a computer; 8) the communication facilities.

2. On the formation of the concepts "information" and "entropy"

The central question of Inf.- Cyb. PW is related to the determination of information (I.) and methods for measuring it. The term "information" appeared in the XIX century from the word "form" and meant something formalizing and ordering [9, 11]. Some scientists absolutize information, claiming that the objects around us are allegedly created from I., others deny the existence of I. as a material substance. Currently, there are three approaches to the concept "information": 1) attributive (philosophy, physics): I. – diversity, reflected in any objects and processes, semantic property of matter, its inherent attribute. Information is the organizing principle in living and inanimate nature, it has existed and will always exist; 2) functional (Cybernetics, physiology and biology): I. – a form of reflection and control function that exists only in cybernetic

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systems. Information implements the control function in biological, social and sociotechnical (human-machine) systems. In systems that have not reached the level of mental development, the concepts “information” and “signal” are equivalent; 3) anthropocentric approach (linguistics, sociology, psychology): I. exists in the minds of people, that is, in systems that have reached a mental level of development; it is the semantic content of a message received from the outside world, and not the physical properties of any signals (light, sound, etc.).

Some proponents of the attributive approach mistakenly think that there is the “matrix” (large-volume memory device) that stores information about the coordinates and speeds of all microparticles in the Universe. They assumed that there is a measuring device (MD) which continuously performs measurements and records their results in the “matrix”. Modern science claims that it can not be, since: 1) it is impossible to explain the functioning of this MD and "matrix"; 2) it is impossible to find the place of the Universe where they are located; 3) any measurement is carried out with an error and requires time; 4) in the measurement process the interaction of the measuring device with a microparticle occurs, at which it changes state; 5) it is impossible to explain the formation of MD and the “matrix”, taking into account that in the early stages of the Universe evolution, the temperature exceeded 10^{12} K. Therefore, to speak of the “the matrix” existence is meaningless.

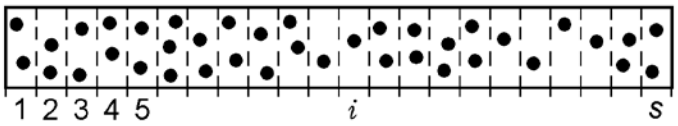

Fig. 3. To a discussion on formation of concept “message entropy”.

To improve the consistency of knowledge, the intersubject links between computer science, physics and mathematics should be established. For example, we can show how the concept of “message entropy” is related to the physical system entropy. Let there are N gas molecules in a vessel of volume V (Fig. 3). We divide the vessel into s equal elementary volumes and calculate the number of molecules n_i in each i-th volume (i = 1, 2, ... , s). You can describe the state of this system using a message consisting of s numbers. Its entropy is the disorder measure in the system. It is calculated using a formula similar to Shannon's:

$$H = -\sum_{i=1}^{s} \frac{n_i}{N} \ln\left(\frac{n_i}{N}\right) = -\sum_{i=1}^{s} p_i \ln(p_i),$$

where $p_i = n_i / N$ и $N=n_1+n_2+\ldots+n_S$. If the molecules are distributed completely randomly and uniformly, then $N / n_i = s$ and the entropy is equal to $H = ln(s) = ln(N/n_i) = – ln(p)$. When the system is maximally ordered, all N molecules are inside the same k-th elementary volume ($p_k = 1$; $p_j = 0$, when j is not equal to k); the entropy H is equal to 0.

3. Features of the information-cybernetic world picture formation

Under the Inf.-Cyb. PW formation method we understand the set of principles, forms and methods of organization of education, which allow us to create in the minds of schoolchildren or students its main components and connections between them. In this case, it uses the most important general didactic principles of: scientificness, accessibility, visualization, sequential complication of the studied material, structural and logical organization of training, consistency and systematicity, consciousness, independence and activity, continuity, profile orientation, unity of concrete and abstract, the relationship of theory and practice, the productivity and reliability of training, an individual and group approach. The principle of modular teaching can also be used, in which the educational material is divided into separate modules (for example, “encoding of text information”, “number systems”, etc.), and modules – into didactic units [4].

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For the formation of interconnected and versatile knowledge, skills and abilities associated with Inf.-Cyb. PW in students' mind of the pedagogical University, it is necessary to use science-intensive educational technologies that include psychological, general pedagogical and didactic methods based on the use of computer technology. For example, when studying the theory of algorithms, the traditional teaching method can be combined with computer modeling of the Post machine (PM), Turing machine (TM) and normal Markov algorithms (NMA), discussed in the textbook [19]. The proposed programs in Pascal implement the corresponding algorithm and help answer the question about the algorithmic solvability of the problem under discussion. The advantage of such computer models is that they allow you to analyze several rather complex algorithms for PM (TM or NMA) that perform from 50 to 100 steps with different input data during one session. It is very difficult to do the same manually (on a blackboard or in a notebook) and it will require a lot of time.

Let us consider the solution of the problem for multiplying two integers written in the unary number system using the normal Markov algorithm. Fig. 4 shows the system of normal substitutions, and on the right – the result of its application to the input word 1111*111 (i.e. 4*3). After completing 64 steps, the response is 111111111111 (i.e. 12). The program takes no more than half a minute to work; students can easily verify the universality of this algorithm by applying it to other input words.

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'*11' → 'A*1'  ||   1 1111A*11 |  substitution  1
'*1'  → 'A'    ||   2 1111AA*1 |  substitution  1
'1A'  → 'A1B'  ||   3 1111AAA  |  substitution  2
'BA'  → 'AB'   ||   4 111A1BAA |  substitution  3
'B1'  → '1B'   ||   . . . . . . . . . . . . . . .
'A1'  → 'A'    ||  62 1111111111BB |  substitution  8
'AB'  → 'B'    ||  63 11111111111B |  substitution  8
'B'   → '1'    ||  64 111111111111 |  substitution  8
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Fig. 4. Multiplication of two integers using the normal Markov algorithm.

The information and cybernetic students' thinking develops not only at the information disciplines study. For example:

1. In electronics lessons, students get acquainted with the operation of digital chips and computer nodes (logic elements, triggers, scrambler, decoder, adder, multiplexer, demultiplexer, DAC, ADC), learn the principle of computer operation, the information processing methods, the principles of radio, television, cellular communication.

2. In robotics classes, students learn to create robots that allow them to implement and study closed and open control circuits [20]. This can be created as cybernetic devices: 1) the robot with ultrasonic sensor, which moves to the obstacle, and finding him, pulls back, rotates to a specified angle, and again goes forward; 2) the robot with an ultrasonic sensor that keeps at a given distance from an obstacle; when an obstacle moves away, the robot goes forward towards it, and when the obstacle comes nearer, the robot moves away from it; 3) a robot with an optical sensor controlled by light; with an increase in the brightness of the lamp, the robot moves away from it, and with a decrease, the robot comes nearer to lamp so that the illumination of the optical sensor remains approximately constant. The last two devices allow to demonstrate homeostasis.

3. Studying the natural science picture of the world, students get acquainted with the main ideas of biological cybernetics, covering general issues of the information control, storage, processing and transmission in living systems, as well as methods of constructing artificial organs. They learn that the inheritance of the main features of ancestral life forms is explained by the biological laws of genetic information transmission with help the DNA molecules using the nucleotides sequence. Each organism individually, the biocenosis and the biosphere as a whole are

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examples of complex cybernetic systems that implement closed and open control chains and homeostasis.

4. Studying physiology, psychology and other human sciences, students are introduced to the ideas of bioinformatics, medical and psychological cybernetics, which allow them to explain the work of the respiratory, cardiovascular, digestive and nervous systems, the development of thinking and memory. They also learn that the application of the information-cybernetic approach in psychology has led to the development of the personality theory and psychology [18], in which a person is considered as a self-regulating information system that evolves due to the implementation of information needs, and his personality is the reflection result of huge number of the information actions. At the same time, personal development can be represented as a change in the principles of information behavior.

5. In pedagogy lessons, students get acquainted with the application of the cybernetic approach in didactics (cybernetic pedagogy), study the direct and feedbacks formed in didactic systems, as well as the programmed teaching principles and the computers using in the lesson.

6. By studying history, economics and sociology, students gain knowledge about methods of managing the demographic situation, economy, and society as a whole; they are learned with concrete examples about the concrete examples of feedbacks arising from the various reforms implementation.

When working on coursework and graduation projects, students can create and experimentally study the following computer-based cybernetic systems [21, 22]: 1) the open and closed engine control system; 2) the automatic speed control system; 3) the closed opto-electronic system for automatic illumination control; 4) the technological process control model.

Summary

The article substantiates the need to use the concept of “educational information-cybernetic picture of the world” and analyzes the problem of Inf.- Cyb. PW construction in the minds of schoolchildren and students. At the same time, its content is determined, a logical-semantic model is presented, and the features of its formation in consciousness of the pedagogical specialties students are discussed. It is shown that the information and cybernetic picture of the world includes the main provisions of the theories of information, coding, communication, control, computer modeling, algorithmization, programming, robotics, as well as the physical principles of various information and cybernetic devices. Various aspects of the concept “information” are analyzed, the question about the relationship of the concept “entropy” in computer science and physics is discussed. To increase students’ interest and enhance their educational and cognitive activities, a computer program is used that implements the normal Markov algorithm and allows one to test various problems for their algorithmic solvability. In addition, the formation features of an informational-cybernetic picture of the world during the study of the disciplines of the informational, natural science and humanitarian cycles in a pedagogical university are revealed.

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