Information in the Context of Education

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Information and information processes are cornerstones of education. However, the knowledge about these processes given by conventional information theories is not adequate to the peculiarities of education. That is why these theories are not efficiently applied to the problems of education. In this paper, we consider a new approach in information sciences. It is called the general theory of information. It is demonstrated how the new knowledge obtained in the general theory of information provides a new insight for teaching and learning.

Introduction

Information is one of the central issues for education. All processes and characteristics of teaching and learning involve information transmission, reception, memorizing, and processing. As an example of such characteristics we can take the student's learning style. Dunn (1990) defines learning style as "… *the way each learner begins to concentrate, process, and retain new and difficult information*." We see that operations with information are in the center of the learning style concept. The concept of learning style is very important for education A growing body of research suggests that increased learning gains can be achieved when instruction is designed with students' learning styles in mind. When teaching takes into account learning styles, then the process of learning becomes more feasible for students. They are able to get more knowledge and to acquire better skills. In addition to this, attention to learning styles and learner diversity has been shown to increase student motivation to learn (Hein and Budny,1999). Learning style is inherently connected to thinking style (Sternburg, 1990), which is also important for education and has essential information characteristics. Another essential component of education is communication. All teaching is realized through communication. At the same time, the main characteristic of communication is information transmission and reception.

Thus, we come to the conclusion that if we know more about information, we will be able to develop education more efficiently. However, it is possible to argue that people have been learning and teaching for thousands of years without precise knowledge about information. Thus, we may ask the question why it is so important for education to have this knowledge. To understand this situation properly, let us compare education to medicine. For thousands of years, people had cured different diseases before microbes were discovered and the main cause for illnesses was explained. However, the discovery of microbes accelerated the development of medicine to an unpredictable extent. Now a great amount of diseases that were lethal even a hundred years ago are curable. Many diseases have been eliminated or almost eliminated in the modern society. In a similar way, a correct answer to the question what information is will provide for finding regularities of information functioning. In its turn, knowledge of these regularities would make available an essential improvement of teaching and learning.

To find such knowledge, It is natural to look into information sciences. There we come upon a peculiar situation. On one hand, it has a lot of theories, a diversity of results, and even a proclaimed success. Scientists created a diversity of information theories: statistical or Shannon's, semantic, algorithmic, qualitative, dynamic and so on. On the other hand, as it is written at the very beginning of one authoritative book on information policy, "*Our main problem is that we do not really know what information is*." Thus, it is not surprising that trying to apply well-known information theories to education, we encounter many difficulties and achieve very little.

However, a new theory appeared recently. It is called the general theory of information and has incorporated all other known theories of information. Its principal achievement is that it explains and determines what information is. The new approach changes drastically our understanding of information, this one of the most important phenomena of our world. It displays that what people call information is, as a rule, only a container of information but not information itself. It reveals fascinating relations between matter, knowledge, energy, and information.

In addition to this, the general theory of information gives means for discovering new types and kinds of information that were unknown before. The conventional type is called *cognitive* information because it gives knowledge and supplies data. It is demonstrated that besides cognitive information, there exist two other important types: the *emotional* or *affective* and *regulative* or *effective* information. This discovery is supported by various neurophysiological and neuropsychological data. All three types of information are studied by *the theory of the triadic mental information*.

Emotions and, consequently, emotional information is essential for education, although other types of information are also essential for it. So, it is not surprising that general theory of information provides efficient means for a study of education. Moreover, the general theory of information reverses our understanding of education. From this new perspective, both teaching and learning are recreative processes, which on the highest levels include different types of creativity.

Contemporary Information Studies and General Theory of Information

Norbert Wiener was the first who considered information beyond its day-to-day usage. He wrote that *information is neither matter nor energy*. This contains the message that the actual objects used for communication, i.e., for conveying information, are unimportant. Since that time, information science emerged giving birth to many information theories and producing a quantity of definitions of information. The birth of information theory is placed officially in 1948, when Claude Shannon published his first epoch-making paper.

The most popular idea is that information is a message or communication. But a message is not information because the same message can contain a lot of information for one person and no information for another person.

The most utilized scientific definition of information tells us that *Information is the eliminated uncertainty.*

Another version has a more general form: *Information is the eliminated uncertainty or reflected variety.*

Both definitions are based on Shannon's information theory (Shannon, 1948). It represents statistical approach and is the most popular now. However, Leon Brillouin wrote that in this theory "the human aspect of information" is completely ignored. As a result, statistical approach has been very misleading in social sciences and humanities.

In (O'Brien, 1995), which is used as a textbook at universities and colleges, it is written that terms *data* and *information* are used interchangeably, but while *data are raw material resources*, *information are data that has been transformed into a meaningful and useful context*. In (Laudon, 1996), we find a similar notion: information is *an organized collection of data that can be understood*. One more definition gives Rochester (1996): *information is an* *organized collection of facts and data*. This definition is developed by Rochester through building a hierarchy in which data are transformed into information into knowledge into wisdom. Thus, information appears as an intermediate level leading from data to knowledge. Ignoring that an "*organized collection*" is not a sufficiently exact concept, it is possible to come to a conclusion that we have an appropriate definition of information. This definition and similar ones are used in a lot of monographs and textbooks being the most popular now. It gives an impression that we actually have a working concept.

Many will say, "*If such definition exists and people who are experts in computer science use it, then what's wrong with it? Why we need something else?"* To explain why this definition is incoherent, let us consider some examples. The first one is a text that contains a lot of highly organized data, but is written in Chinese. An individual, who does not know Chinese, cannot understand this text. Consequently, it contains no information for this person because she cannot distinct this text from a senseless collection of hieroglyphs. Thus, we have a collection of organized data, which contains information only for those who know Chinese. Consequently, information is something different from this collection of organized data.

It is possible to speculate that this collection of data is really information but it is accessible only by those who can understand the text. In our case, they are those who know Chinese. Nevertheless, this is not the case. To explain this, we consider the second example: a text, which is a review paper in mathematics. Three people, a high level mathematician A, a mathematics major B, and a layman C, encounter a paper, which is in the field of the expertise of A. After all three of them read or tried to read the paper, they come to the following conclusion. The paper contains very little information for A because he already knows what is written in it. The paper contains no information for C because he does not understand it. The paper contains a lot of information for B because he can understand it and knows very little about the material that is presented in it. So, the paper contains different information for each of them. At the same time, data in the paper are not changing as well as their organization.

This vividly shows that data, even with a high organization, and information have an extremely distinct nature. Structuring and restructuring cannot eliminate these distinctions. This correlates with Wilson's approach (1993): "In the real world … we frequently receive communications of facts, data, news, or whatever which leave us more confused than ever. Under the formal definition these communications contain no information…"

In spite of a multitude of papers and books concerning information and a lot of studies in this area, many important properties of information are unknown. As writes Wilson (1993), " 'Information' is such a widely used word such a commonsensical word, that it may seem surprising that it has given 'information scientists' so much trouble over the years." It is not only a theoretical necessity but is a practical demand. Considering the United States of America in the information age, Giuliano (1983) states that the "informatization process is very poorly understood. One of the reasons for this is that information work is very often seen as overhead; as something that is necessary but not contributory."

It is possible to compare the development of information sciences with the history of geometry. At first, different geometrical objects (lines, angles, circles, triangles etc.) were investigated. When an adequate knowledge base of properties of geometrical objects was created, a new step was taken by introduction of the axiomatic theory - Euclidean geometry. In a similar way, knowledge obtained in various directions (statistical (Shannon, 1948), semantic (Bar-Hillel, Carnap, 1958), algorithmic (Kolmogorov, 1965; Chaitin, 1966), qualitative (Mazur, 1984), Fisher information (Frieden, 1998), etc.) of information theory as well as practical experience of information technology, made it possible to take a new step - to elaborate a unifying theory. It is called the general theory of information. This theory includes all other directions in information sciences and is developed on the base of axiomatic methodology (Burgin, 1994; 1997).

Information studies have a two-fold aim. On one hand, we want to understand what is information, how it exists and functions. On the other hand, to achieve this goal, it is necessary to know how to get this knowledge. In other words, we need to find how to acquire information about information properties and to derive regularities of information functioning. In accordance with this two-fold aim, the set of the main principles of the general theory of information consists of two groups: basic ontological and axiological principles. Basic ontological principles reflect the most essential properties of information as a natural, social, and technological phenomenon as well as regularities of information functioning. Basic axiological principles explain how to measure and evaluate information. They systematize and unify different, existing as well as possible, approaches to construction and utilization of information measures.

Ontological Principles of the General Theory of Information

Ontological Principle O1. *I*t is necessary to separate information in general from information (or a portion of information) for a system R. In other words, empirically, it is possible to speak only about information (or a portion of information) for a system.

Why it is so important? The reason is that all conventional theories of information assume that information exists as something absolute, like time in the Newtonian dynamics. Consequently, this absolute information may be measured, used, and transmitted. In some abstract sense it is true, but on practice, or as scientists say, empirically, this is not so.

Ontological Principle O2. In a broad sense, information I for a system R is any essence that causes changes in the system R.

Definition 1. The system R is called the receiver of the information I.

This principle has several consequences. First, information is closely connected with transformation. Second, it explains why information influences society and individuals. Namely, reception of information implies transformation. This is important for education. According to Principle O2, teacher does not transmit knowledge to students. Teacher transmits information. If this information is relevant and students accept it, then after receiving they transform accepted information into knowledge. Consequently, everything in a teaching process has to be aimed at optimization of information processes. This has to be the principal criterion of the teacher activity. As any activity, it consists of three stages: a) Design (Planning); b) Realization; c) Evaluation. The basic essence for each of these stages is information.

Third, Principle O2 makes it possible to separate different kinds of information. For example, any person as well as any computer has many kinds of memory. It is even supposed that each part of the brain has several types of memory agencies that work in somewhat different ways, to suit particular purposes. Each of these memory agencies is a separate system and it is useful to study differences between information that changes each type of memory. This helps to understand the interplay between stability and flexibility of mind, in general, and memory, in particular.

Definition 2. A subsystem IF(R) of the system R is called an infological system of R if IF(R) contains infological elements.

Infological elements are different kinds of structures (Burgin, 1991; 1997). Let us take as a standard example of infological elements knowledge, data, images, ideas, fancies, abstractions, beliefs, etc. If we consider only knowledge and data, then the infological system is the system of knowledge, which is called in cybernetics a thesaurus. This system is very important for education because the primary goal of teaching is to give knowledge, while the central aim of learning is to acquire knowledge.

When R is a material system, its infological subsystem IF(R) consists of three components: a material component, which is a system of physical objects; a functional structure realized by the material component; and the system of infological elements. For example, the material component of the infological subsystem of a human being is her/his brains. The corresponding functional structure is her/his mind. Infological elements in this case will be constituents of the knowledge of the individual. Another example of an infological system is the memory of a computer. Such a memory is a place in which data and programs are stored.

Ontological Principle O2a. Information in the strict sense or, simply, information for a system R, is everything that changes the infological system IF(R) of the system R.

This implies that for a complex system there are different kinds of information. Each infological system determines a specific kind of information. For example, information that causes changes in the system of knowledge is called cognitive information. This kind of information is crucial for pedagogy.

It is possible to argue that the concept of an infological system is too ambiguous and fuzzy. However, ambiguity may be a positive property if you can use it. For example, if you can control and change ambiguity, it becomes not an ambiguity but a parameter that is utilized to tune and control the system. This is just the case with the infological system. Thus, it is natural that a human being has not the same infological system as a biological cell or a computer.

The fact that information influences human behavior to such a great extent is a consequence of the fact that human infological systems control human actions. The latter is a necessary trait for adaptation.

Let I be some portion of information for a system R.

Ontological Principle O3. There is always some carrier C of the information I.

Really, people get information from books, magazines, TV and radio sets, computers, and from other people. To store information people use their brains, paper, tapes, and computer disks.

Carriers of information belong to three classes: material, mental, and structural. For example, let us consider a book. It is a physical carrier of information. However, it contains information only because some meaningful text is printed in it. The text is the structural carrier of information. Besides, the text is understood if it represents some knowledge of people. This knowledge is the mental carrier of information in the book.

Ontological Principle OM3. There is some substance C that contains information I.

Definition 3. This substance C is called the physical carrier of I.

Ontological Principle O4. A transaction of information goes on only in some interaction of C with R.

This interaction may be direct or indirect when it is realized by means of some other objects.

Ontological Principle O4a. A system R receives information I only if some carrier C of I transmits I to the system R or R extracts this information from C through some channel ch.

We have two ways of information transaction: transmission and extraction. Transmission of information is the passive transaction with respect to R when R receives information and active transaction with respect to C when C transmits information. Extraction is the active transaction with respect to R when R extracts information and passive transaction with respect to C when information is taken fromC. When the carrier C is the system R itself, then we have the third type of information operations – information processing. It includes information transformation and production (Burgin, 1997).

The two ways of information exchange reflect interesting regularities of education. There is an essential difference between the Western and Eastern approaches to education. The main principle of the Western tradition is that a teacher comes to students to teach them. Contrary to this, the main principle of the Eastern tradition is that a student comes to teacher to learn from him. This means that the Western approach is based on information transmission, while the Eastern approach stems from information extraction.

This explains the current situation with education technology. Its contemporary level is appropriate only for information extraction. To be effective for information transmission, it has to become intelligent. Thus, lack of intelligent software causes low efficiency of computer programs for teaching and learning because students are accustomed to the active role of a teacher and cannot accommodate themselves to active customers of information provided by computer.

Ontological Principle O5. A system R accepts information I only if the transaction causes corresponding transformations.

Ontological Principle O6. One and the same carrier C can contain different portions of information for one and the same system R.

Really, let the system R be some person A and C be a book written in Japanese. At first, A does not know Japanese and C contains almost no information for A. After some time, A learns Japanese, reads the book C and finds in it a lot of valuable information for himself. Note that knowing Japanese A is, in some sense, another person.

In the same way, a student has to be prepared for acceptation of information communicated by a teacher. This is done on several levels. The college level solves the problem of preparation by a system of prerequisites: to enroll into a course A, a student have to have knowledge from the courses, for example, B, C, and D. Material of these courses constitute a base for the course A. On the group level, teacher organizes the course material so that each topic of the course is based either on the prerequisites or on the previous topics of this course. On the individual level, teacher tests student knowledge and, if necessary, helps the student to catch up with the exposition of the material.

Typology of Information

The model example of an infological system is the system of knowledge. Consequently, what people have in mind speaking about information is implicitly included in the notion of cognitive information. This is the reason why even experts do not make distinctions between information and knowledge or information and data. It is not a simple task to separate substantial essences, knowledge and data, from cognitive information that transforms these essences. However, researchers have found that learning is essentially connected to emotions (pleasure, amusement, and gratification) and to intentions (interest and attention). At the first glance it seems that information has very little to do (if anything) with these aspects of human personality because information is usually considered as something opposite to emotions and intentions. For example, such understanding is reflected in the statement that three main goals of communication are to inform, to entertain, and to persuade. However, this is a fallacy based on the conventional model of information. To resolve this inconsistency, we need to find infological systems related to emotions and intentions.

A solution is given by the theory of the triune brain and behavior, of Paul MacLean (1973). The main idea is existence of three levels of perception that are controlled by three corresponding centers of perception in the human brain. These three centers together form the triune brain. MacLean asserts that centuries of evolution have endowed people with three distinct cerebral systems. He calls the oldest of these the reptilian brain. It programs behavior that is primarily related to instinctual actions based on ancestral learning and memories. Through evolution, people have developed a second cerebral system - the paleomammalian brain. This system plays an important role in human emotional behavior. The most recent addition to the cerebral hierarchy is the neomammalian brain, or the neocortex. It receives its information from the external environment as registered through the eyes, ears, and other senses. This brain processes information in a logical and algorithmic way. It governs people creative and intellectual functions.

The triune brain is a neuropsychological construction that has to be related to a model of personality to achieve a correct understanding of mental processes. Psychologists have elaborated many models of personality (cf., Ryckman, 1993). Some models have been suggested by sociologists. Here we use the extensive model of personality, which has a hierarchical structure and incorporates other models of personality, both psychological and sociological (Burgin, 1997a).

According to the extensive model, the material component of personality consists of ten layers (levels). Each layer consists of three parts. Each part constitutes a definite system and represents some essential feature of a person. On the psychological level of personality each part has three components: a system or brain scheme (actual or virtual), a process that is realized in this system and through which the corresponding feature emerges, and what is produced by this system.

Here, we are mostly interested in the second layer. It contains three systems: intellect or the center of reasoning mostly based on rational information processing; the center of emotions and feelings, and the center of will, intentions, and presuppositions. They correspond to such features as intelligence, feeling/emotions, and will.

Comparing the second layer of personality to the triune brain, we come to a conclusion that the reptilian brain during the years of evolution has expanded to a more complex system and acquired additional functions. Those are the functions for the advanced regulation of the human behavior. Consequently, we call this system the Center of Will.

Thus, we come to three basic systems of the brain: the Center of Reasoning or System of Intelligence, the Center (System) of Feelings and Emotions, and the Center (System) of Will and Instinct.

The Center of Reasoning realizes rational thinking. It includes both symbol and image processing, which go on in different hemispheres of the brain. The Center of Feelings and Emotions governs sensibility and the emotional sphere of personality. The Center of Will and Instincts directs behavior and thinking. Two other centers influence behavior only through the will. For example, a person can know that it is necessary to help others, especially, those who are in need and deserve helping. But this person does nothing without a will to help. In a similar way, we know situations when an individual loves somebody but does not show this in any way due to an absence of a sufficient will.

Discussing will, we distinguish *conscious will*, *unconscious will*, and *instinct*. All of them are controlled by the Center of Will. Usually, people do not make distinctions between thoughts about intentions to do something and the actual will to do this. Thoughts belong to the Center of Intelligence, while the will is situated in the Center of Will. In other words, thoughts and words about wishes and intentions may be deceptive if they are not based on will.

Taking each of these three centers as a specific infological system, we discover three types of information. One is the conventional information that acts on the center of reasoning in the neocortex. This information gives knowledge and is called cognitive. Information of the second type acts on the emotive center, which is situated in the paleomammalian brain. This information is called emotive or affective information. Information of the third type acts on the center of will. This information is called regulative or effective information.

It is necessary to remark that other types and kinds of information may be separated if we consider other subsystems of the brain and the whole nervous system as its infological systems. For example, people have five senses: vision, hearing, smell, touch, and taste. A specific system in the nervous system including the brain corresponds to each of the senses. For example, the visual cortex in the brain controls vision. Consequently, we can consider the visual, sound, olfactory, tactile, and gustatory information.

All three centers constantly interact exchanging information. In such a way, knowledge from the center of reasoning influences emotions and behavior. This is the basic postulate of the cognitive therapy. Emotions and feeling affect reasoning and behavior, in particular, decision-making (Ketelaar and Goodie, 1998). Will controls emotions and reasoning. For example, some recollections, which are knowledge from the past, provoke grief, amusement or happiness of an individual. Knowledge of the laws causes definite behavior of a citizen. As have discovered psychologists, positive emotions help in cognition, learning and remembering. Will changes direction of the cognitive processes of a scientist. Conscious or unconscious will cause attraction or distraction of attention and so on.

Education is based on all three types of information, although the emphasis is always done on the cognitive information. However, emotional information is also important for education, and to teach better, we have to know more about this type of information. However, people know about feelings and emotions but do not know about emotional information. Moreover, as it is stated by Minsky (1986), “many people think emotion is harder to explain than intellect.” Development of the theory of affective information, as a part of the theory of the triadic mental information, might help to explain the emotional sphere of a personality.

Conclusion

Thus, we come to the conclusion that while knowledge is important for teaching, information plays a vital role. However, the main emphasis in teaching/learning processes has been traditionally made on knowledge. For example, a special type that is called content knowledge is separated as a necessary prerequisite for successful teaching. Explicating distinctions between knowledge, data, and information, general theory of information reverses our comprehension of teaching and learning processes. Knowledge is necessary but without skills for communication, information transmission, and process organization, this knowledge will be unattainable and thus, useless for students giving them no information.

Metaphors help us to understand better different situations. There are two competing metaphors of teaching. The first one compares a student with an empty vessel. In a pedagogical interaction, teacher fills this “vessel,” primarily with knowledge. The second metaphor comprehends student as a candle or torch. In a pedagogical interaction, teacher puts this “torch/candle” on fire. In the pedagogical interpretation, fire symbolizes individual activity aimed at a search for knowledge. In both cases, it is assumed that the teacher conveys knowledge to the student.

However, the general theory of information explains that teacher does not transmit knowledge. Teacher communicates information, which may become knowledge or not. Consequently, the real situation in teaching lies between those cases that are depicted by the “vessel” and “fire” metaphors. To represent it, we use the “mill” metaphor, which compares a student to a mill. According to this metaphor, teacher supplies this “mill” with information, which is like grains for a real mill. The “mill” transforms these “grains” into the “flour” of knowledge, skills, and experience. The “mill” metaphor implies that teacher has to give good “grains” for the student’s intellectual “mill.” As it is known, if a mill is supplied by quality wheat, it will produce good flour. If you put weeds into a mill, its output will not be a convenient food for people.

Supplying a mill with grains resembles filling a vessel, but this is not the same. Really, in addition to such filling, a teacher has to take care of the “mill” to make it work properly and efficiently. Moreover, the teacher develops this “mill” so that it becomes able to grind more and more advanced “grains.”

It is interesting that a similar process has been discovered on the molecular level of information transmission. It is known that the DNA of an organism contains complete information the organism structure and functioning. The carrier of this information is the genetic code of amino acid sequences. The diversity of life is based on the same chemical machinery: DNA and RNA to store genetic information that encodes for proteins. They carry out vital cellular chemical reactions resulting in a variety of chemical compounds. For a long time, it was assumed that the DNA sequences are replicated in RNA. Replication corresponds to the direct transmission of knowledge. However, biologists have discovered that codons in RNA transcripts of genes are altered after transcription by editing of the RNA (Keegan, et al, 2000). According to the general theory of information, it means that at first information from DNA to RNA is transmitted. Then this information is transformed into knowledge by editing.

A new insight is achieved not only for teaching, but also for learning. Basing on the general theory of information, we figure out that learning is acceptation of information, while a student transforms the accepted information into knowledge, then we understand that a student cannot acquire knowledge directly. This implies importance of the critical approach in learning. It means that to have sound and correct knowledge, a student have to question more or less everything that he or she is learning. Such attitude gives much better results than simple memorizing. For example, algebra and geometry are often taught by memorizing: in one situation do this, in another situation do that… No wonder that students remember very little (if anything) of the course material. If people construct, they understand; then they can recreate what they need later, when they need it.

The general theory of information also explains why emotions are so important for teaching/learning. There are, at least, three reasons for this. First, moderate positive emotions stabilize nervous processes and in such a way facilitate comprehension and thinking. At the same time, negative or very strong positive emotions destabilize functioning of the nervous system having a negative impact on learning and creative processes. Second, when information reception is connected to emotions, it makes memorizing stronger. Third, emotions influence learning motivation.

In addition to this, information studies in the pedagogical perspective are essentially important for the development of technology in education, both in the traditional and extended meanings (Burgin, 1999). The main reason for this is that a teacher can use her/his intuition, personal implicit knowledge, and experience for teaching, while an instructional computer program is based only on a part of explicit pedagogical knowledge, which is coded by a programmer.

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