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# Information and Cognitive Technologies
# in the Context of the 4th Technological Revolution:
# Educational Aspects

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*Subject of the work: information and knowledge technologies as a key element of the 4th industrial revolution. These technologies are represented by a variety of Smart technologies, the scope of which is constantly expanding. However, there are still many unexplored features and capacities of these technologies.*

*The purpose of this work is to analyse educational capacity of information-knowledge technologies and to formulate the strategies of their implementation at universities and secondary schools.*

*The research methodology is based on the concept of convergence, according to which new technologies emerge from the convergence of both established and new technologies.*

*The result of the analysis of the educational capabilities of information and cognitive technologies suggests that the technology of the full cycle information prevails in the field of education. This technology allows shifting from data to information and from information to knowledge.*

*The area of application of the results includes educational standards, textbooks and teaching aids, programs of additional professional education.*

*Keywords: information and cognitive technologies, technological revolution, big data, artificial intelligence, robotics.*

*Research area: system analysis, management and information processing.*

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## Introduction

Information technologies (IT), and then information and communication technologies (ICT) have dramatically changed the entire human civilization by providing unprecedented opportunities for storage, processing, transfer of huge arrays of various information. The first thing to change was the structure of human activity: the information factor now plays the most important role in it. The social consequences of IT and ICT implementation were extraordinarily relevant, serving as a basis for the development and spreading of social networks and the society informatization process, including informatization of education. At the present moment, informatization process has been acquiring some qualitatively new properties. There appeared the concept of "digital economy", assuming transformation of information into a basic economic category, rapid development of the information business and market. Cloud, additive, quantum etc. technologies have appeared and are intensively developing. However, the digital revolution (often referred to as the 3rd revolution) is nothing but a prelude to the new, larger-scale 4th industrial revolution.

The manifesto formulating the typical properties of this revolution is an article in the *Foreign Affairs* magazine written by Klaus Martin Schwab, the founder and president of the World Economic Forum. This magazine is a remarkable place for publishing: it is a body of the Council on Foreign Relations that makes a controlling influence on the USA policy (it would be enough to mention that in 1979–1985 this organization was headed by David Rockefeller). Therefore, the subject matter is not a spontaneous process, but a politically motivated movement with global objectives and global means of achieving them. Specification of those objectives and development of those means are among the major topics of the Davos forum. It is worthwhile noticing that it is not the only example of bringing the post-industrial revolution ideologists and high-level politicians together. It is greatly proven by Z. Brzeziński who was not just an influential politician, but also a serious researcher who laid the foundation for the entire post-industrial society concept.

The 4th industrial revolution ideology is based on the two theses:

The first thesis is that the 4th revolution is a natural and inevitable period of the production and entire civilization development, the so-called "Industry 4.0".

The second thesis states that the 4th industrial revolution generates a range of systems and technologies that go far beyond the boundaries of the industry as such. Approximately, a set of such systems and technologies looks as follows: modelling, integrative systems, Internet of things, cybersecurity, cloud computing, additive manufacturing, augmented reality, Big Data, autonomous robots etc.

The discussion of the validity and inevitability of these theses goes beyond the scope of this article. However, we should remark that at the present moment they form the core of structure, actively and consistently implemented in large geographic spaces. Let us just provide some comments.

According to Schwab, the fourth revolution is qualitatively different from the third, digital industrial revolution in the following aspects.

The fourth revolution is developing at an exclusively **fast pace.** Such development may be referred to as exponential, which is linked, particularly, to the exponential growth of unstructured data and the need for an adequate reply to this challenge.

The comprehensive synthesis of various technologies (**'width and depth'**). At that, the changes do not only concern the technological, economic and social spheres of life, but also the human personality itself.

The fourth revolution has a **systematic character,** encompassing not only particular sectors of economy and social institutions, but also the entire society as a whole (Schwab, 2016).

All these are supplemented with the statements that the artificial intelligence forming the conceptual core of the fourth revolution will finally make it possible to make production to 'face the human'. According to Schwab, reliance upon artificial intelligence is a way of individualizing production and releasing only the goods requested by an individual. Besides the personal aspect, this transformation is expected to yield a relevant economic effect.

These statements may be illustrated with the demand for professional skills forecasted for 2020 (Schwab, 2016):

Cognitive abilities — growing demand 52 %;

Systemic abilities — 42 %;

Complex problem solving — 40 %;

Content writing skills — 40 %;

General skills — 37 %;

Communication skills — 37 %;

Resource management skills — 36 %;

Technical skills — 33 %;

Physical skills — 4 %.

One of the critical ideas of the fourth revolution is the Internet of things. According to the revolution ideologists, the critical moment will come when a trillion (!) various sensors are connected to the Internet; it will create a large number of "smart" things ("all things will become smart"). These things are capable of communicating with each other and making decisions on their own, without interference of man.

The opportunities provided by 3D printing are also impressive. According to analysts, the critical volume of consumer goods produced with 3D printing is 5 %; when this amount is reached, standard consumer goods can be printed locally with more personification options and significant reduction of the logistic expenses.

Just like any other revolution, the 4ᵗʰ industrial revolution makes up a certain forecast for the future, combining realistic understanding of the new opportunities with the projects where emotions prevail over logic. Such projects include:

− unlimited prolongation of life (starting from 2029);

− invention of a non-biological intelligence that overcomes the biological one (2040);

− development of a wireless connection of the biological and artificial intelligence (2045).

Similar ideas occur at any large-scale social movement and should be evaluated rationally (Kondakov, 2017)

## Theoretical framework

The program described above deserves an extremely serious attitude.

On the other hand, it also needs independent analysis for correspondence of the formulated subject matter to the actual situation and real tendencies taking place in the economy and the society.

It appears important, since the precedent when a comprehensive social forecast happens to be fatally *incorrect* has just been provided by the recent "information society" story.

Let us give a brief illustration of this idea presenting the analysis of this social formation carried out in a previous research (Shutikova, 2009).

Traditionally, "information society" is defined as a society saturated with various computer technologies, where information becomes a commodity. This is the only compulsory condition for considering a society to be an "information society". However,

"information society" is quite a definite social formation specifically described in the works by D. Bell, A. Touraine, A. Toffler, Z. Brzeziński, Y. Masuda etc.

Generalizing the forecasts of the researchers named above, the main properties of this social organization may be listed as follows:

a) the determinant of social life in an information society is scientific knowledge, which is frequently equalled to information. The main social institution of such society is a university as a centre of production, processing and accumulation of knowledge (information).

b) social differentiation is determined, first of all, by the level of awareness, not material factors. Therefore, social conflicts are shifted from the economic sphere to the spheres of information and culture.

c) the main infrastructure of an information society consists of informatization technologies, not material production. In the future, the symbiosis of the social and information structures is expected to be formed.

It is obvious that the described model of information society hardly conformed to the reality. It may be explained by the fact that the information society ideologists explicitly (or, more likely, implicitly) equalled knowledge to information.

Analysis of the information phenomenon reveals the following components in it:

− message, i. e. some content;

− interpretation of the message (content);

− communication as transfer of symbols coding the content.

From the point of view of the information society theorists, the main component of this triad is the content, embodying some knowledge of a given subject. In reality, the dominating component is the interim part, communication. This fact dramatically changes the entire understanding of information. It is now seen not as a synonym of knowledge, but as a basis for making this or that decision. The electronic portfolio technology, popular at universities and high education establishments as a "digital fingerprint", "digital achievement record" of the students helps recruiters find potential job candidates (Smolianinova, Shilina 2011).

Such approach provides a key to understanding many phenomena of the information society, and, therefore, the digital one. For instance, advertising is not a means of "informing" the customer of the positive properties of goods or services. Its purpose is to create an image of some goods or services to provoke a person to perform a certain action, i. e. to purchase those goods or services. Such an image is created by means of various operations with the symbols transmitted through communication channels.

The arguments above demonstrate that the social and economic processes determined by the information factor may happen to be much more complicated than seen even by the most influential analysts. For this reason, it appears rational to separate the objective tendencies of information and technological spheres' development within the 4th industrial revolution from the speculative abstractly-political structures.

Implementation of this idea yields the following result.

In the development of the modern civilization's technological base, we may clearly find the *convergent* dominant. It is about considering the new technologies, serving as milestones for the new stages of development, as convergence of the "old" technologies with some socially significant kinds of activities. Particularly, the shift from the information technologies to the information-communication ones may be considered from the angle of convergence of IT with the socially significant communicative activity. It appears especially reasonable to regard the Internet development from the perspective of such convergence.

It can be also said that the internal ideological driver of the fourth information revolution is convergence: the convergence of the information-communication and cognitive technologies. Externally, this convergence is generating (and has already generated) a series of technological and social phenomena linked, first of all, to the development of intellectual information systems (Internet of things, virtual and augmented reality, autonomous robots etc.).

The tendency to intellectualization of the information activity has both particular, or fundamental (**a**) and metaphysical (**b**) grounds that embody a certain opinion on the super-objective of the human civilization.

(**a**) The particular fundamental problem causing qualitative changes in the technological sphere are related to the Big Data processing problem which, in its turn, emerged in the context of automation of production and other economically and socially relevant information processes.

The automation idea marks the entire modern civilization. This is what is seen as the key factor for its prosperity: "*Civilization advances by extending the number of important operations, which we can perform without thinking about them*", said famous English philosopher A. Whitehead. This or that way, automation has penetrated into all spheres of human life, generating, this way, a next, qualitatively new stage of automation. In the majority of cases, man is not capable of competing with an automated device due to the limited volume of information man can process. In this situation, there emerges a need for connecting automated devices to each other, uniting them into

a cycle. As expected, it yields a dramatic rise of labour efficiency. The connection of automated devices is the essence of the above mentioned "Industry 4.0".

(**b**) Discussing the problem of the role played by cognitive technologies in the modern society, it is wrong to ignore the following circumstance. The development of technologies in the intellectualization aspect has fundamental ideological (and even metaphysical) prerequisites. Intellectualization of technology is the super-objective of the entire western civilization. It would be enough to recall R. Descartes, G. Leibniz, R. Lullius, F. Viète and any others. I. Newton, known as the founder of modern physical theory, was also the author of an artificial language made for some computational device. "Great aims seem foolish at the outset: but we'll laugh at Chance itself, yet, and brains, with thoughts to celebrate, in the future, a Thinker will create" wrote Johann Wolfgang von Goethe more than 200 years before the beginning of the fourth industrial revolution. The poem itself, however, is commonly known as an encyclopaedia of the West European world outlook (such things are impossible to imagine in works of A. S. Pushkin, for instance).

This remark appears especially important, as the manifestos of that revolution inevitably contain the said irrational component. As this thought does not completely fit the Russian mentality, it should be "taken off the table" to focus exclusively on the pragmatic aspect.

From this pragmatic point of view, we may state the presence of an objective systemic **challenge** connected, first of all, to the exponential growth of the disembodied information, which in the future creates a threat of blurring all the established borders.

The presence of this challenge is also manifested in language. According to the famous Sapir–Whorf hypothesis, any socially relevant phenomenon would be reflected in a language. In all European languages we find three terms: "data", "information", and "knowledge". At that, *data* are understood as *facts and ideas,* presented in the form of symbols for the purpose of transferring, processing and interpreting them; *information* is a *meaning* assigned to the data based on the known facts and idea presentation rules. Structured (with causal and other relations) systematic information makes up *knowledge.*

The presence of such division speaks in favour of the objective and fundamental nature of the said challenge.

For the education sphere alone, it can be said that the general strategy of the challenge response may be double-barrelled.

✓ Creation of the "smart technologies" capable of structuring various data, extracting needed information on the basis of which they, without interference of man, can make some decisions. Such technologies are, doubtlessly, useful for education, but the scope of their use has not been clearly defined. Moreover, it may be suggested that a number of technologies from the list above can be adjusted for education purposes. It is true for cloud technologies, augmented reality technologies etc. At that, it is worthwhile emphasizing that no information-communication or Smart technologies can solve the modern education issues on their own. Moreover, the use of such technologies in the education process and in further professional activity requires a significant advanced training to raise even the "trivial user" level. It would be ungrounded to think that smart technologies may start "thinking" for their user. Smart technologies, even those with the user-friendliest interface, demand smart attitude and operation.

✓ Development of the education system in the aspect of developing, first of all, the curriculum content, and, on the other hand, the inter-subject "patterns" for establishment of the interdisciplinary relations and, therefore, ensuring the integrity required for the emergence of "smart" technologies. Such integrity may ensure the development of the knowledge paradigm only in the conditions where, besides the knowledge, "data" and "information" are also circulating in the society. At all that, it is necessary to remark that the term of "knowledge" remains the basic term of education, together with the "action approach" and "competence approach". It is provided by the new Federal Law of the Russian Federation "On Education in the Russian Federation", according to which the purpose of education is the development of personality and acquisition of basic knowledge, skills, abilities under the secondary general education curriculum, and development of the competences necessary for life in the society, conscious professional orientation and professional education.

Indeed, these aspects are two sides of one integrated whole. However, the second aspect plays the dominating role. It is the driver of innovations in the entire sphere of information and technologies. This situation partially reminds of the situation established in 1984, when the task for development of computer skills of the youth and introduction of computer science into the school curriculum (back then, known as "Basic information and computer science") was first set.

Back then, there was neither material resource for informatization nor experience of new subject introduction at the education institutions. But nevertheless, due to the so-called "algorithmic language" developed by academician A. P. Ershov, which was not a computer language but incarnated the basic programming ideology, the

Russian computer science course became the leading tool in the computer skill development.

This example illustrates the statement, that among the three classic problem-solving components, the material, technological and intellectual ones, the main attention should be given to the intellectual base, and, first of all, to the development of necessary knowledge.

## Statement of the problem

Since the 4th industrial revolution is, first of all, a revolution of technology, the implementation of such new technologies into education is the "royal way" of implementing the revolution in the sphere of education. In this regard, Smart technologies appear to be a natural way of ICT development.

For example, VR, visualization technologies can be actively used for foreign language teaching to ensure:
 − *credibility* of the situation, to create the sense of reality;
 − *interactive* communication with the environment;
 − *presence* effect (clearly structured visualization of a scenario involves all organs of senses of the learner).

Dialogue capabilities of the system are provided with the artificial intelligence technologies, and, particularly, recognition and generation of speech.

The 4th industrial revolution technologies appear to be a property that brings dramatic changes to the social, economic and education landscapes. However, these external processes do not always cover all the changes caused by such technologies. The answer to the question "Which technologies form the core of the 4th industrial revolution and how can they be used in education?" is the main subject of the research presented in this article.

Let us consider the following example.

More and more employers today use the so-called "human cloud" to solve a wide range of problems. Professional activity is divided into a number of projects offered to the virtual community of contractors who may be located anywhere in the world. The implementation of this method becomes possible due to cloud platforms (Schwab, 2016). In this situation, the employer has no minimum wage or income tax payment obligations; moreover, it eliminates the need for handling all the employment formalities. Due to the reasons mentioned above, this form of labour relations, despite its obvious negative sides, is gaining more and more momentum.

Apart from the economic and social aspects of the problem, we may see the following:

The tasks offered to the "cloud community" may be classified into two types:

−   the tasks allowing relatively simple formalization, possible to solve under some known patterns with the known tools;

−   poorly structured and formulated tasks impossible to solve with a set of standard procedures and tools.

For the solution of the first type tasks, a set of traditional competences common for any college graduate is usually enough.

The second type tasks can only be solved with an expanded range of competence. For instance, it may require:

−   creation of a thesaurus reflecting the scope of problem for all project participants to develop the same understanding of the same items;

−   ability to present the scope of problem with a system of signs common for all project participants etc.

Therefore, a certain social and economic program happens to be concentrated around definite and certain knowledge and cognitive skills.

This situation is common.

Analysis of the various suggestions on the use of "smart" technologies in education, presented, particularly, in the proceedings of the "*Smart Education and E-Learning*" international forum concerns, first of all, the technological aspects; however, in the process of implementation the essential component is the cognitive one. To be brief, ***"smart" technologies need smart users.***

This conclusion sets a number of principally new requirements to the new education, related, first of all, to the development of the cognitive component of the content. But first, it is important to remark that such a task for the education system has never been set before, and returning to the "good old past" is now impossible. Nevertheless, Russian education provides a number of solutions that appear to be important and promising from both the point of view of information-cognitive technologies and preparation of the young generation for the creation and implementation of innovations.

The keynote of the innovative book on technology edited by S. A. Beshenkov (written by S. A. Beshenkov, M. I. Shutikova, E. V. Mindzaeva et al.) is "Learning how to learn", which is aimed at the acquisition of information and cognitive skills (Tekhnologiia, 2017).

The components of the technologies (in the terms of the said textbook) are:
- ✓ learn how to read;
- ✓ learn how to define;
- ✓ learn how to memorize;
- ✓ learn how to think;
- ✓ learn how to present information;
- ✓ learn how to reason;
- ✓ learn how to discuss;
- ✓ learn how to solve problems;
- ✓ learn how to research;
- ✓ learn how to work on a project.

The search for components of the information-cognitive technologies relevant for the promotion of the innovations and technologies of the 4th industrial revolution is going on all over the world. Thus, R. Shank lists twelve fundamental cognitive processes: modelling, experiment, forecast, assessment, diagnosis, planning, causality, judgement, negotiation or argument, influence, team work, description. According to him, these processes would make a consistent basis for education adequate to the dramatic changes happening in the modern science, technology, and industry (Shank, 1989).

It is also worthwhile noticing that the cognitive approach ideas were introduced into pedagogy in various forms a long time ago.

Among the cognitive approach-based education technologies, there are:
- − logical and conceptual models (V. E. Shteinberg);
- − logical structure of academic text (A. M. Sokhor);
- − web chart presentation of information (E. A. Rakitina, V. Iu. Lyskova);
- − frame-based knowledge presentation (R. V. Gurina, E. E. Sokolova);
- − cognitive visualization-based didactic object modelling (N. N. Man'ko);
- − hypertext information presentation;
- − intellect card-based association visualization (E. A. Bershadskaia);
- − presentation of a subject with semantic networks (T. G. Shikhnabieva etc.);
- − theory of inventive problem solving (TIPS) (G. S. Altshuller and successors) etc.

Indeed, the 4th industrial revolution has its specificity and scope of application. The experience described above should be considered in the analysis of opportunities provided by Smart technologies.

It is also necessary to remark that the difference between "knowledge" and "information" has been long recognized in pedagogy. For example, according

to A. S. Konarzhevsky, knowledge differs from information in the following properties: depth, generalization, particularity, systematicity, mobility, deliberateness, compactness, expansiveness, consistency, flexibility, completeness, strength. In this regard, pedagogy has been following the trends that are capturing the entire society now.

## Methods

The main method for analysis of the new education opportunities provided by the 4th industrial revolution technologies is the method of convergence. It highlights the information-cognitive technologies as convergence of information-communication technologies and cognitive technologies. It reveals a common context where new technologies appear, and ICT may be also regarded as convergence of information technologies and the technologies of communication sphere.

## Discussion

Development of the 4th industrial revolution technologies brings out radical changes in the structure of production, business models, methods and means of communication. On one hand, research of the readiness of the population for accepting the 4th industrial revolution technologies demonstrates, that to implement such technologies until 2025, Russia needs 5.8–9.2 million highly qualified specialists of the "Knowledge" category; however, only 17 % of the people engaged in the sphere of economy possess unique knowledge (2017–2018, employer survey carried out by The Boston Consulting Group international consulting company).

This way, knowledge is becoming an economic category to a greater and greater extent. P. Drucker expressed an idea that in the new economic conditions, knowledge becomes a resource equal to other traditional economic resources. But he said even more: knowledge becomes the only resource bearing critical value both in the economic and social senses. In the long run, it leads to the emergence of the "knowledge society", which, according to I. Iu. Alekseeva, has the following characteristics (Alekseeva, 2009):

− common recognition of the role of knowledge as a condition of success in any sphere of activity;

− continuous need for new knowledge required for the solution of new tasks, creation of new kinds of products and services;

− emergence of large production and knowledge transfer systems;

‒ mutual stimulation of the knowledge supply and demand (supply tends to satisfy the existing knowledge demand and form the demand);

‒ efficient interaction between knowledge generating systems/subsystems, material goods producing systems/subsystems within various organizations and the society as a whole.

Unfortunately, today there are more serious problems in the acquisition of knowledge at the general education level. As a matter of fact, students today are just collecting information that does not become knowledge for them (Beshenkov, Shutikova, Mindzaeva, 2016).

This circumstance (replacement of knowledge with information) is observed everywhere, causing worries at the highest levels.

According to the concept presented in the "Towards Knowledge Societies" UNESCO world report, the main task of the modern times is the qualitative transformation of information into knowledge. The critical factor of this process is education, which is intended to help people realize that information remains just a corpus of data, not necessarily correctly interpreted; excess of information does not necessarily mean increment of knowledge.

Development of knowledge is the basic condition for implementation of the 4th revolution technologies.

The knowledge may be classified into the following categories:

‒ factual domain knowledge composed of qualitative and quantitative characteristics of the studied objects;

‒ algorithmic (procedural) knowledge: knowledge of methods, means, procedures, leading to the determined result under certain conditions;

‒ conceptual, notional knowledge, composed of the understood aggregation of terms used in this or that field of study.

Methodological knowledge: knowledge of general tendencies in the studied phenomena and processes.

In the conditions for the fourth industrial revolution, the critical role is played by the methodological, meta-domain knowledge.

That is methodological knowledge (meta-knowledge) needed for the development of systemic vision of the surrounding world.

Even G. W. Leibniz underlined that we understand something only to the extent we can understand another thing and so on. This way, we can only say that we have understood something when we can decompose it into parts, understandable on their

own. In fact, this is the formulation of the fundamental metaknowledge element: the principle of reductionism underlying many technologies, including 3D technologies, robotics etc.

The role of such principles in the establishment of the world outlook and development of the analytical component of the professional activity is really big. They do not only set the world outlook "matrix", but also get applied in various spheres of human activity. This way, the solution of problems, structuring information do not only depend on the knowledge and skills of the person or their competences, but the general vision of the problem. This fact is well-known to all the professional education specialists; but it is rarely considered in the teaching process when the competence approach dominates.

However, the conscious perception and integrative activity, typical for the 4th industrial revolution technologies, are impossible without general scientific ideas and the world outlook being an integral part of the scientific, academic, and professional activity.

The roots of such integration go back to the 1930-s. In the brief, but substantial article "The Age of the World Picture" by M. Heidegger (1938) a new turn in the scientific thought was found: exploration of the world "as a picture", as a totality, a system (the "system approach" term appeared later, in the works by L. von Bertalanffy). It should be noted that the unitotality idea was the key idea in Russian philosophy, starting from V. S. Solovyev.

In the framework of the natural science subjects, particularly, mathematics and physics, general scientific principles were formulated and found relevant for the entire cycle of disciplines. They played the role of the integrating element for the whole modern knowledge. S. A. Beshenkov, M. I. Shutikova, E. A. Rakitina (Beshenkov, 2008) formulate some of those principles, particularly:

- systematicity principle;
- symmetry principle and associated conservation laws;
- uncertainty principle and associated complementarity principle;
- formalization incompleteness principle;
- non-linearity principle.

The authors underline, that one of the most important objectives of the general scientific principles are the expansion of the world cognition horizon beyond the immediate perception, or, speaking the language of informatics, acquisition of the maximally complete information of the surrounding world.

In the modern Big Data world, these principles make up the core of the meta-knowledge (i. e. present some universal intellectual patterns) that offer structuring the unformulated data and making headway to knowledge.

In modern terminology, the "meta" prefix is used to define systems used for studying and/or describing other systems. Such systems are called "meta-systems". The mainstream of modern science and practice is determined by the mindset for search for integral paradigms and meta-paradigms of knowledge, for achievement of the fullest and the most adequate comprehension of the studied reality. According to one of the greatest physicists of the 20th century E. Schrödinger, today's unprecedented expansion of scientific knowledge and its growing specialization require a whole and integrated world outlook more than ever.

It is also proven by the presence of the said principles in very different contexts.

For example, the principle of uncertainty, formulated by Heisenberg for quantum mechanics ("it is impossible to determine accurately both the position and the direction and speed of a particle at the same instant") is actively, though a little differently, applied, for instance, in translation theory ("it is impossible to provide the translation of the meaning and the stylistic peculiarities of the text at the same time").

In the digital society, where the critical role is played by the 4th industrial revolution technology, the determining part is played by the information principles, i. e. the principles related to the fundamental information theory notions in this or that way. Moreover, the principles formulated above are more and more often interpreted in the information context.

For example, let us take the complementarity principle of N. Bohr, which primarily stated that a whole phenomenon should be described through mutually complementary ideas; formulated by Iu. M. Lotman, the principle changed as follows: "no matter how much we expand the circle of our data, the need for information will continue developing, running ahead of our scientific progress. Therefore, with the growth of knowledge, the ignorance will not decrease, but grow, and the growing efficiency of activity will not simplify, but complicate it. In these conditions, the lack of information is compensated with its "stereoscopicity", or the possibility of acquiring an absolutely different projection of the same reality" (Beshenkov, 2008).

General information principles may include, for instance:
- general formalization thesis;
- information modelling principle;
- information administration principle;

- digital coding universality principle.

Now, let us comment.

The main formalization thesis (introduced by S. A. Beshenkov) is one of the leading information principles of separating object from its notion. This principle is linked to the so-called "Frege semiotic triangle" which presents the connection between the thing (denotate), sign (name) and concept (meaning). The immediate consequences of the main formalization principle are:

- independence of signs to the denotate;
- possibility of formal sign manipulation;
- possibility of multiple interpretation of the signs.

The information modelling principle can be formulated as follows: every object may be described at a certain degree of completeness in one of the known languages. Actually, the subject matter is the main principle of cognition: an object not represented in a language remains "a thing in itself". In the digital society, the concept of information model acquires special importance, since VR technologies may convert an information model into a pseudo-real object. All these demonstrate that information modelling may be regarded as an important information principle (Shutikova, Mozolin, 2005).

The information administration principle is one of the basic ones, stating that in the digital society the administrating influence is based, first of all, on information. That generates the administration methods not studied by traditional cybernetics. The subject matter is, first of all, the administration of structurally unstable systems with little influence. The research of such questions was started by J. H. Poincaré and continued by R. Thom, V. I. Arnold et al.

Understanding of such principles and ability to apply them in a certain situation make up the basis for meta-knowledge. Let us underline it one more time that it is the meta-knowledge that makes the platform necessary for the generation of innovation, without which the 4th industrial revolution as such would be impossible.

The said principles may be (and are) used in the pedagogical practice for the establishment of the least expected interdisciplinary links, which play the primary role in the generation of new solutions.

Example.

The symmetry principle may manifest itself in extremely interesting and unexpected ways. According to the research carried out by Russian scientist S. V. Petukhov, working at the Biomechanics Department of the Institute of Machine Science of the

Russian Academy of Sciences, it is possible to find the same regular patterns in the human genome symmetry structure and the tables of the famous Chinese tractate Yi Ching (Book of Changes, app. 700 BC).

This example illustrates the profound unity of the world (in this case, biology, mathematics, and culture). The recognition of this unity and the proper use of the opportunities revealed in this unity is one of the main "super-objectives" of the 4th industrial revolution. Let us remark that the patterns discovered by S. V. Petukhov formed the foundation of one of the Smart technologies: modelling the interference immunity of genetic system (Petukhov, Petukhova, 2006).

## Conclusion / Results

1. The 4th industrial revolution has a significant ideological component that manifests the values intrinsic for the west European civilization. Literal adherence to these values and mindsets will inevitably throw our society back to the support roles, to the position of the eternal "chaser". Moreover, the "Trojan horse" option is also possible, when some technologies are announced and promoted as the leading ones in order to engage competitors into an intellectual and technological race. This option is not impossible. It may be even suggested that such technology can be quantum technologies, or the computation technologies based on the quantum superposition principle. The prospects of such technologies are so impressive that large companies are ready to pay any price to create at least a model of such quantum computer. Unfortunately, the challenges of this process are not merely technical, but also ideological (Diiakonov, 2018).

Nevertheless, the challenges of digital society are the objective reality that needs to be considered by all social institutions, including the education system. It is extremely important to determine these challenges with maximum precision and to concentrate all attention on the solution of these truly fundamental problems for the entire society.

2. Within the 4th technological revolution, it is suggested to take a series of drastic actions to reform the education system. It includes a combination of doubtlessly rational and correct actions with the projects unjustified from either economic or pedagogical points of view, and designed, mostly, to create a "big shock". The suggestions that seem to be rational on their own often appear not to make any system when combined. For example, it is suggested: (Kondakov, 2016):

– to implement the postulate that the holistic view of things is the foundation of the learning process;

– to implement the large-scale project activity;

– to implement digital education resources etc.

Each of these provisions is generally correct and rational, but it is extremely hard to bring them together under the same logic. Development of a holistic view of the world requires a certain degree of academism and implementation of full-scale knowledge paradigm. Project-making is a strictly technological approach. Bringing them together is ideologically challenging, especially in a limited number of academic hours (but indeed, possibly that should be explicitly expressed).

3. Creation of the educational Smart software industry appears premature. It is an extremely expensive and labour-intensive initiative with an indefinite pedagogical effect. Even though some software products would be doubtlessly useful for education (cloud technologies, augmented reality, intellect cards), some useful software can be already found in the open access, such as the intellect card making software (XMind) etc. Relying upon the ICT introduction experience it may be suggested that time will show, which software is really needed at schools.

4. It is required to establish a theoretical base to be not a mere user of the 4th industrial revolution technologies, but a potential creator (which, notably, is mentioned in the new technological education concept). This theoretical base is formed by the domain knowledge and some universal meta-knowledge. The experience of such "pro-active" performance also exists (Beshenkov, 2016). In the 1990-s, when no clear facilities and resources for the announced informatization of education were available, some cheap, but clear and well-designed intellectual actions yielded impressive results thanks to the applied universal approaches (the most famous example being the algorithmic language of A. P. Ershov).

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# Информационно-когнитивные технологии в контексте 4-ой технологической революции: образовательные аспекты

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*Предметом настоящей работы является анализ образовательных аспектов 4-ой промышленной революции как нового этапа развития экономической, социальной и технологической сферы. Ключевым элементом этой революции стали «умные технологии», способные генерировать структуры знаний и осуществлять общение без участия человека. Это говорит о необходимости перехода к новым информационно-когнитивным технологиям, которые расширяют класс информационно-коммуникационных технологий.*

*Цель работы — выявление образовательных возможностей информационно-когнитивных технологий.*

*Методология исследования свойств информационно-когнитивных технологий основана на концепции конвергенции информационно-коммуникационных и когнитивных технологий, что позволяет увидеть новые возможности этих технологий и обрисовать сферы их применения в образовании.*

*Результат данного исследования — обоснование необходимости введения в содержание обучения «метазнаний» — общенаучных принципов, позволяющих трансформировать данные в информацию, а информацию в знание.*

*Область применения полученных результатов: образовательные стандарты, учебники и учебные пособия, программы дополнительного профессионального образования.*

*Ключевые слова: информационно-когнитивные технологии, технологическая революция, большие данные, искусственный интеллект, робототехника.*

*Научная специальность: 05.13.01 — системный анализ, управление и обработка информации.*