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Cognitive Space for Online and Offline Learning: A Convergent Approach

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Abstract

This article is devoted to the creation of an information and educational environment for hybrid learning on a transdisciplinary basis. The digitalization of various subject areas causes an increase in their complexity and uncertainty. The cross-fertilization of the natural sciences promotes convergence based on common principles, methods and structures. Multi- and interdisciplinary research in the biomedical sciences is accompanied by both their differentiation (bioinformatics, etc.) and their convergence. The main goal of the article is to create a platform for the exchange of ideas, methods and technologies between physicists, mathematicians and philosophers of natural sciences. The consequence of the perception of the surrounding world through the prism of "numbers" is the fragmentation of knowledge and hidden cognitive problems that create the illusion of knowledge and form complex systemic thinking in the learning process. This, on the one hand, limits the possibilities of online learning, and on the other hand, increases the complexity and virtuality of offline learning. In the context of a pandemic and man-made disasters, this has a detrimental effect on human capital.

Keywords

Cognitive aspects of digitalization, dynamic structure of information flows, extreme principles of natural science, hybrid educational environment, metasciences

1. Introduction

Relevance. Digitalization of education means new opportunities, technologies and methods. However, the rapid digitalization of different subject areas is accompanied by an increase in complexity (statistical, dynamic, structural, algorithmic and informational). At the same time, the mutual enrichment of the natural sciences contributes to interdisciplinary connections, accompanied by their convergence. The increasing complexity of computer and other special disciplines has begun to limit the possibilities of IT and ICT in online learning. The increasing complexity of the dynamic structure of information flows and their uncertainty limits the further development of artificial intelligence (machine and deep learning, etc.) (V. Mygal et al., 2021). At the same time, in different subject areas, a dynamic similarity of information flows of various nature (time series, fractal signals, etc.) was manifested (V. Mygal et al., 2019; A. But et al., 2016). The similarity of the structures of the evolution of dynamic events opened up new possibilities for a holistic understanding of the common nature and unity of knowledge, without which this understanding would not arise. The relevance of the UNESCO and UN recommendations on the transdisciplinarity of education in the 21st century is considered in (V. Mygal et al., 2021).

Digitalization of education: cognitive aspects. In interdisciplinary and multidisciplinary studies, the influence of the psychophysiological state of a person on the perception, presentation and analysis of information flows of various nature has been established (V. Mygal et al., 2019). Transdisciplinary research on hidden connections revealed:

- duality of evolution of natural phenomena and discrete thinking;
- individuality of cognitive activity and a variety of methods for its study;
- relationship between functional asymmetry of the cerebral hemispheres and induced cognitive aspects.

Under the influence of destabilizing factors, these connections cause cognitive distortions (systematic errors) of the student (V. Mygal et al., 2019). It is obvious that the versatility of the manifestation of the dynamic similarity of information sources of various nature causes cognitive dissonance.

Non-obvious generalization: The variety of graphic images of complex dynamic systems (CDS) and its elements develops creative thinking, limiting critical thinking.

Communication of uncertainty and complexity as a source of information. Spatial inhomogeneities of information sources and transmission media induce local temporal distortions (jumps, instabilities and noises) in information flows of various nature. As a result, increases:

- the complexity of the dynamic structure of the interrelations of information sources of various nature;
- uncertainty of transient critical states of self-organized sources of information;
- the influence of the latent relationship between spatial complexity and temporal uncertainty.

In this case, the spatio-temporal relationship of the fields of inhomogeneities is manifested in the dynamic similarity of self-organized processes of various nature. This similarity indicates the structural unity of the physical, physiological and psychological. Indeed, internal and external influences on information sources induce the complexity and uncertainty of the dynamic structure of information flows of various nature (V. Mygal et al., 2019; V. Mygal et al., 2021).

Intuitive generalization: The hidden connection of the complexity of the spatial structure of the information flow with its temporal uncertainty has cognitive and heuristic significance.

Structure-forming and structure-distorting factors. The digitalization of information flows is a structure-forming factor when it transforms the simplicity of nature into the complexity of algorithms. However, the digitalization of education has increased the cognitive complexity of offline learning, which is a structurally distorting factor. Since spatial uncertainty distorts the temporal structure of the information flow, the spatio-temporal connections between them have a cognitive value. Therefore, the methodology of the geometrization of the dynamic structure of information flows of various nature on a transdisciplinary basis will allow us to analyze the spatio-temporal relationships between the elements of the SDS, taking into account the psycho-physiological state of a person. Is it possible to prove everything that is true? The search for an answer to this question has split the communities of mathematicians, physicists and philosophers. Revising their understanding of metaphysics, metamathematics, metaphilosophy, the authors established the cognitive significance of their complementarity. The main goal of the article is to create a platform for the exchange of ideas, methods and technologies between physicists, mathematicians and philosophers of natural knowledge.

2. From interdisciplinarity and multidisciplinarity to transdisciplinarity

2.1. Development of interdisciplinary links and new problems

Mutual enrichment of natural disciplines. The exchange of research methods in the natural sciences made it possible to cross their borders and gain new knowledge. Simplify the study of interdisciplinary relationships extreme principles of natural science, the geometric interpretation of which reflects the dualism of nature.

Therefore, the generator of revolutionary ideas in physics, biology and chemistry has always been geometrization, which made it possible to streamline the world of structures (Loshak Zh., 2005). General methods, structures and extreme principles of physics, biology and chemistry contribute to their convergence (Figure 1).

As can be seen from the figure, convergence is based on the principles of the natural sciences, the commonality of their models and structures. This actualized the study of the relationship between spatial and temporal nanostructures. However, the increasing spatial complexity of structures is accompanied by an increase in temporal uncertainty. This has created new difficulties and problems, which are most evident in the nanoworld.

Non-obvious generalization. Interdisciplinarity of principles, structures and dynamics (functions) is the basis of convergence.

The duality of the complexity of interdisciplinary problems. On the one hand, interdisciplinary research has shown its effectiveness. On the other hand, the complexity and uncertainty of the nanoworld is increasing and has begun to limit the further development of interdisciplinary research. The key to understanding the duality of interdisciplinary problems are:

- difficulties in computer simulation of complex dynamic systems;
- problems of identifying the dynamic structure of information flows of various nature;
- contradictions between the complexity of the structure of simplified digital models and the simplicity of a multifractal nature.

Their duality is based on the asymmetry of relationships and the irreversibility of non-equilibrium systems, which are the factors of spatio-temporal structure formation (Nicolis, Prigogine, 1993).

The study of deterministic chaos in open non-equilibrium systems made it possible to reveal the hidden patterns of the transition of disorder into order in nature. In particular, the study of the diversity of such transitions using the entropy of Boltzmann, Shannon, Kolmogorov, Renier, and others indicates the relationship between the complexity of transition processes and their spatial uncertainty, which determines the manifestation of cognitive aspects (V. Mygal et al., 2021).

An obvious generalization. The development of the uncertainty of interdisciplinary connections increases cognitive duality, which limits the effectiveness of online and offline learning.

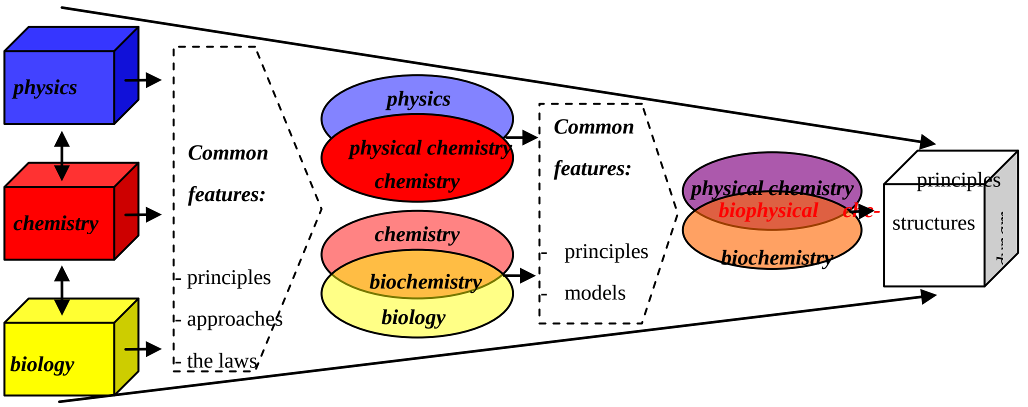


Figure 1. Convergence of natural sciences.

2.2. Transdisciplinarity of problems induced by digitalization

Multidisciplinary approach to the study of interdisciplinary problems of education. They reveal different aspects of the same problem. We highlight three key aspects of the problem:

- an increase in complexity during exposure is accompanied by an increase in uncertainty;
- internal factors create problems in selecting relevant information;
- individuality of cognitive perception generates ambiguity.

All the problems of multidisciplinary research are united by the distortion of information, which gives rise to cognitive dualism and the problems of the philosophy of natural science.

Multidisciplinary studies of neurosciences (neuropsychology, neuroergonomics, neurobiology, neurophysiology) and cognitive sciences (cognitive ergonomics, cognitive linguistics, cognitive psychology) have made it possible to establish contradictions between the linearity of the learning environment and the non-linearity of cognitive activity. In human factors engineering (V. Mygal et al, 2020) the need to reduce risks in training is substantiated.

Obvious generalization. The key to cognition is in the dualism of thinking, the individuality of which is formed by activity.

Fragmentation of knowledge. The variety of sources of information and their increasing complexity contribute to the fragmentation of knowledge (V. Mygal, G. Mygal, 2021). The use of simplified linear models and complex computational algorithms in teaching stimulates the development of creative thinking. At the same time, multidisciplinary and interdisciplinary approaches are not the means of effective protection against knowledge fragmentation. As a result, glare perception of information and discrete thinking, which create the illusion of knowledge (Mygal et al., 2020). Obviously, therefore, the urgent problems of science, education and medicine have become acute in extreme conditions (environmental and man-made disasters, COVID-19 pandemics). Today, the recommendations of UNESCO and the UN on the transdisciplinarity of education in the 21st century are relevant, as well as the report "ARISE-2" (Advancing Research in Science and Engineering), the main goal of which is to make a "transition from interdisciplinarity to transdisciplinarity" (Advancing Research, 2013).

Unintended side effects. The work (Bernstein, 2015) draws attention to the fact that transdisciplinarity includes not only multidisciplinarity and interdisciplinarity. Transdisciplinarity also includes what is between disciplines and beyond. The accelerated development of digital technologies, on the one hand, has provided unprecedented potential benefits for education, science and medicine, and on the other hand, unintended side effects (complexity, uncertainty, cognitive aspects, mental health, etc.) (Rigolot, 2020; V. Mygal et al., 2020). These effects have created many problems, among which the key ones are:

- risk forecasting based on existing mathematical models;
- mental health of the younger generation (discrete thinking, glare perception, etc.).

Solving real problems is impossible without visualizing the dynamic structure of information flows of various nature in the cognitive space, which is based on transdisciplinarity.

Generalization-conclusion. We need transdisciplinary tools not only to understand reality, but also to counteract global challenges.

3. Digitalization of technologies - new opportunities and problems of knowledge

3.1. The dual unity of the processes of cognition and control.

The relationship of knowledge and control. The accelerated digitalization of education has created new problems that are directly related to the processes of management and cognition. These processes include the collection of information, its transmission, accumulation and processing. The use of this information in the process of developing control actions considers the dual unity of the processes of control and cognition, which are based on active reflection and cyclicity (Figure 2).

To predict safety (biological, physical, functional and informational) under unforeseen conditions, a convergent approach and tools on a transdisciplinary basis are needed. The development of critical thinking and intuition in the process of education and professional activity will help maintain human resilience (V. Mygal et al., 2020).

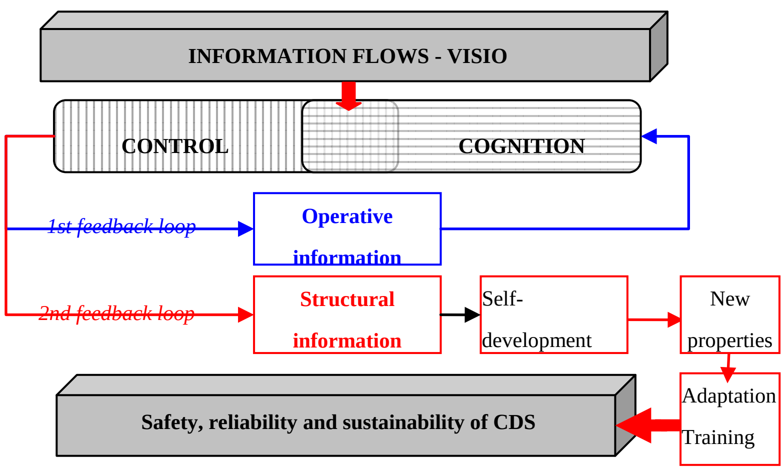
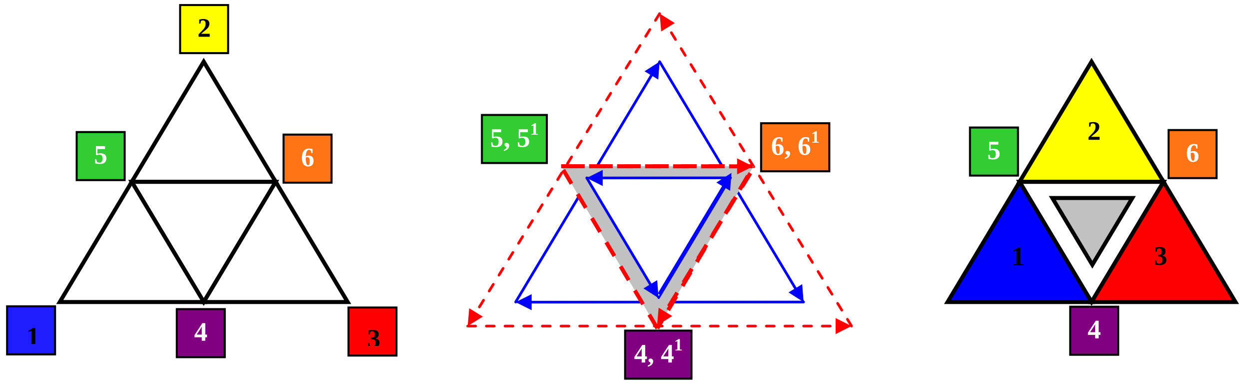


Figure 2. The relationship between cognition and control and their impact on the viability of the SDS.

The problem of the viability of nano-, bio- and information technologies (NBIT). The concept of viability as dynamic stability under normal environmental conditions was introduced by A. A. Bogdanov (Bogdanov, 1989). He showed that within a system, elements that are not viable, unstable, or unreliable can form a viable, stable, and reliable whole. "The significant problems we face cannot be solved with the same level of thinking we used when we created them" (Calaprice, Einstein, 2005, 2011). Obviously, therefore, the idea to realize synergy through the convergence of nano-, bio- and information technologies (NBIT) (Roco, Bainbridge, 2020) failed. The reasons for this become apparent within the framework of the heuristic models of NBIT interconnections that we proposed (Figure 3).

As you can see, all models are similar in form, but differ in content. The static model can be represented dually as a Sierpinski graph or fractal (Mandelbrot, 1988). The dynamic model displays the feedback asymmetry that causes cognitive dualism (see 2.2.). The statistical model displays the instability of the power balance of three subsets of transient microstates. Therefore, models b. and c. complement each other, and a system analysis of all models indicates the instability of the informational balance of technologies. The asymmetry of relationships and the growth in the number of distortions in information flows increases the uncertainty of the dynamic structure, which limits the ability to implement sustainable synergy of NBIT. All this limits the further development of intelligent technologies (machine learning, AI, etc.) (Russel, Norvig, 2003).



a) Static Model – graph b) Dynamic Model c) Statistical Model

Figure 3. Heuristic models of relationships in nano-, bio-, information technology NBIT (1- nanotechnology, 2 - biotechnology, 3 - information technology, 4, 5 and 6 – conjugate states, connections and subsets).

Non-obvious generalization. Synergy of technologies is possible with a balance of hidden relationships in each NBIT technology and all information resources.

Cyber-physical systems as technologies. In cyber-physical systems (CPS), the integration of computing resources with physical processes constantly adapts to external conditions, exploring and learning this environment. The most general form of signal organization is its spatio-temporal, namely its linear invariant (Wiener, 1961). Further disclosure of the concept of the form and structure of the information flow occurred with the transition from a linear invariant - only as a form of an ordered plural - to the concept of mutual ordering of two sets. This principle of mutual ordering of two sets is given by the concept of spatio-temporal isomorphism, which makes the configuration of the dynamic structure of signals (its signature) a kind of code. The structure of mental codes can also be described in terms of spatio-temporal isomorphism. Spatio-temporal relationships in the dynamic structure of information flows of different nature reflect the extreme principle of the shortest path or least curvature developed by Heinrich Hertz based on the ideas of Jacobi and Gauss (Stolzner, 2003). However, in real conditions, the safety of CPS is affected by the human factor.

Obvious generalization. The safety of the CPS is mainly determined by the human-machine interaction.

Metaphysical approach to the individuality of systems. The development of methods for identifying the individuality of biological objects was carried out within the framework of the metaphysical approach (Edwards, 2007; French, 2014). Further development of the metaphysical approach to the functioning of physical and biological systems was carried out on a transdisciplinary basis (V. Mygal et al., 2016; V. Mygal et al., 2018; V. Mygal et al., 2021). In them complementarity of approaches is shown, which is based on:

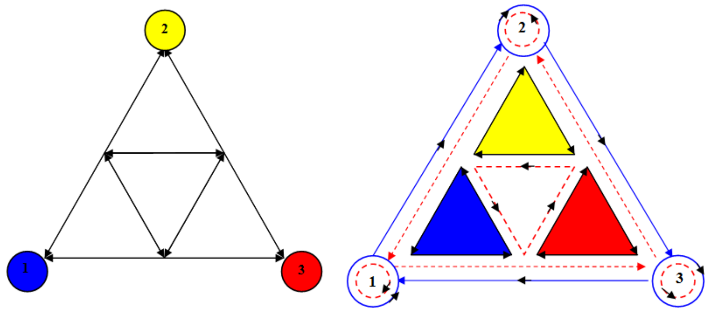
- extreme principles of natural science that have a geometric interpretation;
- theory of dimensions and theory of dynamic similarity;
- the principles of the general theory of relativity, from which follows the movement along a geodesic line (Einstein, 1916).

Complementarity of approaches is due to the manifestation of steepness and curvature of space-time. Further development of the metaphysical approach made it possible to establish the influence of cognitive aspects on information flows of various nature, as well as the influence of the psychophysiological state of a person on them (V. Mygal et al., 2019; V. Mygal et al., 2021). It became obvious where NATURE "hides" the dynamic structure of genetically or technologically inherited codes that determine the individual functioning of self-organized objects.

Intuitive generalization. Information about spatio-temporal codes is hidden in the dynamic structure of CPS control signals.

Heuristic model of a cyber-physical system. Components of a cyber-physical system (physical and digital layers, as well as two interfaces) that interact with each other in time and space. They form a single system, the universal heuristic model of which in unforeseen conditions are the structures of relationships in the statistical and dynamic models of CPS (Figure 4).

As you can see, the stability, reliability and safety of the CPS in extreme conditions characterize its viability. CPS can be represented as: a) a static model in the form of a graph or face of an octahedron, which allows us to consider it also as a fractal figure; b) a dynamic model that contains three feedback loops. The symmetry of static connections and the induced asymmetry of dynamic relationships in unforeseen conditions lead to the loss of CPS stability.



a) Static Model b) Dynamic Model

Figure 4. Heuristic static and dynamic model of a cyber-physical system (1- physical layer, 2- digital layer, 31 и 32 – interfaces).

Intuitive-generalization. The dynamic spatio-temporal structure of information flows of various nature contains a genetic code.

Hereditary information. It can be assumed that hereditary information is hidden in the nature of the restructuring of the control cycle structure. This is confirmed by the results of multidisciplinary studies of self-organized objects of animate and inanimate nature (Mygal, 2016). The evolution of cycles is associated with the phenomenon of self-organized criticality (Bak et al., 1988). This confirms the dynamic similarity of self-organization cycles of media of different nature in the space of dynamic events (Mygal et al., 2017). But how in nature does the adaptation of self-organization cycles not upset the dynamic balance? Especially the problem of imbalance of resources manifested itself in the life sciences, which gave rise to new problems and contradictions. However, the nature of the restructuring of the dynamic structure of transient processes (phases, states, etc.) contains information necessary to study the viability of the CPS and the viability of a person as its key element. It can be assumed that the similarity of the dynamic structure of time series of various nature is due to the self-organization of heterogeneity fields in the sources of information and its transmission media for maximum counteraction (Illiashenko et al., 2021).

Intuitive-generalization. The viability of CPS in extreme conditions determines the resilience of a person, which makes a convergent approach to ensuring their physical, functional and informational security the most effective.

3.2. Life Sciences: Cognitive Aspects of Digital Technologies

Cognitive aspects of the increasing complexity of learning. The integration of information and post-industrial technologies has revealed causal relationships between cognitive aspects and the system complexity of information flows (V. Mygal, G. Mygal, 2019). The differentiation of special disciplines and the development of digital modeling, formal and informational logic have created many difficulties, problems and contradictions, the key ones are:

- difficulties in cognitive perception of the diversity of structures;
- problems of processing fractal signals and a variety of tools for their analysis;
- contradictions between dynamic complexity and simplicity of modeling.

The distortion of information under external and internal influences, which is due to the transitional psychophysiological state of a person, is considered in the work (Mygal et al., 2020).

Obvious generalization. The digitalization of education and the growing complexity of all subject areas form the illusion of knowledge.

Induced cognitive distortions. Causal relationships of cognitive aspects with different types of complexity are considered in the works (Mygal et al., 2020). They show that cognitive distortions are the result of individual perception and representation of complexity, instability and non-linearity. Changing the dynamic structure of the hidden relationships of the information flow determines the functionality of the information source. Therefore, cognitive distortions create difficulties, problems and contradictions, which are caused by an increase in induced complexity (V. Mygal et al., 2020; V. Mygal et al., 2021). The key ones are:

- difficulties in selecting relevant sources of information;

- problems of effective selection of operators (pilots, etc.), as well as their admission to work;
- contradictions in the understanding of the same terms in different subject areas.

Induced complexity causes desynchronization of information flows, which worsens the mental health of students. The solution to the problems of increasing complexity and uncertainty in the multidisciplinary cognitive space has not been achieved (Mygal V. et al., 2021). As a consequence, further differentiation of special disciplines.

Generalization – conclusion. Distortion of the structure of information flows of information induces hidden cognitive distortions (individual systematic deviations).

Convergence of the life sciences. The multidisciplinary development of biomedical sciences is accompanied by their active convergence with other disciplines, as well as their differentiation (bionanoresearch, bioinformatics, etc.). The widespread use of neurosciences (neuroergonomics, neuropsychology, etc.) has revealed that cognitive problems depend on the compatibility of their cognitive styles. Therefore, the study of activities in the digital world limits many difficulties, problems and contradictions. The key ones to study are:

- difficulties in perception, presentation and analysis of poorly formalized information;
- problems of studying the features of thinking and identifying cognitive distortions;
- contradictions between the style of thinking and methods of processing, presentation and analysis of information.

All of them are connected with the complexity of discrete thinking, which is based on intuition. When implementing individual scenarios of adaptation to external influences, a person intuitively uses the flexible logic of antonyms (Figure 5).

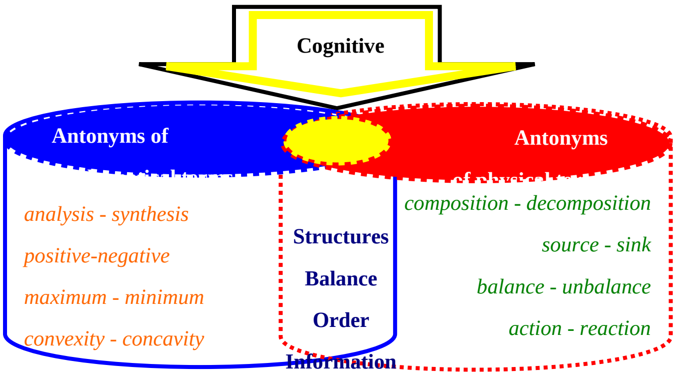


Figure 5. Connection of mathematical and physical antonyms.

The similarity of mathematical and physical antonyms manifests itself in spatio-temporal relationships, which, from complementary angles of view, reflect changes in structure, balance and order. Obviously, cognitive dualism is associated with an intuitive search for a spatio-temporal balance between extremes.

Not an obvious generalization. The duality of perception of nature, individuality of thinking and functional asymmetry of the cerebral hemispheres determines the features of cognitive activity and mental health.

4. Information challenges in online and offline learning

4.1. Increasing conflict in the learning environment

Crisis of education. The global environmental and social challenge is a crisis of values, ideas, attitudes and knowledge and, therefore, primarily a crisis of education (A. Einstein, Cortese, 2003). This is manifested in the increasing complexity of interaction in a digitized world. The manifestation of cognitive dualism in different subject areas has common features that are associated with a change in the dynamic structure of the information flow when exposed. The destabilizing effect is created by the induced self-organization of many spatial inhomogeneities in physical and biological systems (Illiashenko et al., 2021). The growth of complexity and uncertainty in the digital modeling of real processes creates cognitive difficulties, problems and contradictions in learning. The key ones are:

- difficulties in perceiving information flows of various nature;
- problems of processing fractal and non-linear signals;
- contradictions between reality and virtuality.

All of them are caused by local violations of the dynamic and energy balance in information flows of various nature, which lead to spatio-temporal inconsistency. In our opinion, this inconsistency leads to new difficulties and problems that are associated with the manifestation of the human factor phenomenon (V. Mygal et al., 2021).

Generalization-conclusion. Features of communication and technical features of the most electronic information and educational environment provoke conflict.

Problems of learning online and offline. The use of auxiliary digital tools greatly simplifies learning. At the same time, the effectiveness of online and offline learning depends on obvious factors and less obvious factors. Among the many problems of online and offline learning, the key is the increasing complexity and conflict of interaction (V. Mygal et al., 2016; V. Mygal et al., 2018). The study of the structural complexity of information flows of various nature in a multidisciplinary cognitive space has revealed many problems and contradictions that affect the cognitive style. Keys among them are contradictions between the real and virtual world, causing cognitive dissonance. The difference between the levels of ICT competence of a student and a teacher increases the conflict in the electronic information and educational environment.

Generalization-conclusion. Learning both online and offline mainly develops creative thinking.

Information challenges in a digitized world. Ergonomic studies of human-computer interaction have shown that information calls are based on the multidimensionality of the measure of information and individual characteristics of thinking (V. P. Mygal et al., 2019). This increases the structural complexity and creates new problems (Figure 6).

As we can see, on the one hand, the increase in structural complexity leads to new knowledge, and on the other hand, to the vision of new problems. The use of a variety of study methods and a variety of graphic images of one object does not allow achieving a "cognitive" effect. Unfortunately, the use of many abstract forms in special disciplines does not evoke direct associations among students, which does not stimulate them to think in more general forms and use intuition.

An obvious generalization. Distortion of information increases the conflict of all types of interaction in the learning environment, which limits the occurrence of a "cognitive" effect.

Formation of cognitive style. The growing number of parameters, patterns and criteria creates real problems. The problem of reliability of information is important, for the solution of which the key ones are:

- criteria of individuality, which are common to different sciences, but do not play the same role in every science;
- criteria for the reliability of operational and structural information;
- criteria for the quality of information.

The work (V. Mygal et al., 2020) shows that the problems of machine and deep learning are associated with the complexity and variety of cognitive graphics tools, the perception of which is influenced by the psychophysiological state of a person. This does not allow revealing the hidden spatio-temporal patterns of functioning of the SDS elements, which contribute to harmonization in the formation of a cognitive style. Hidden cognitive problems limit the intellectual support of online self-learning and increase the complexity and virtuality of offline learning. After all, we discover new knowledge thanks to intellectual intuition, and not recognizability of a symbol or graphic image of an object.

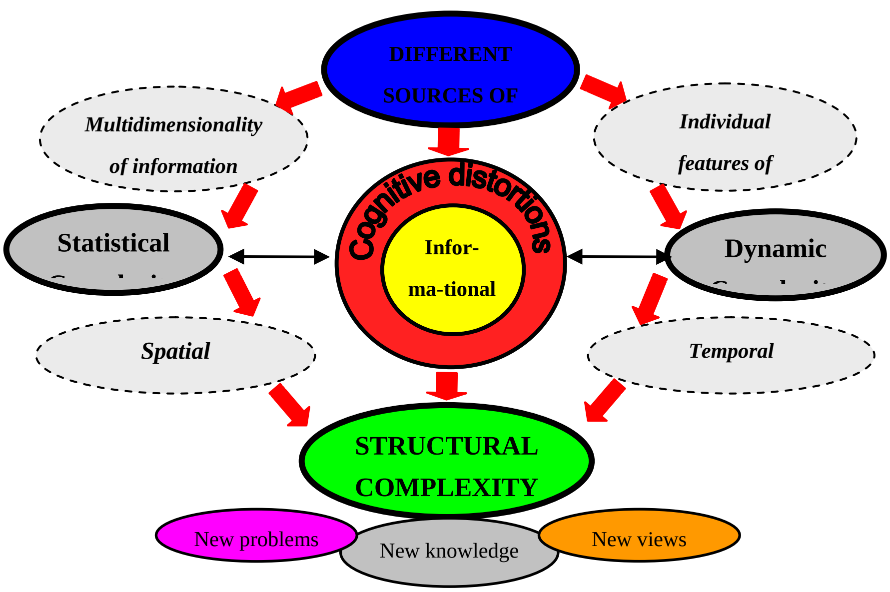


Figure 6. Duality of information flows.

Obvious generalization. The individual features of thinking are formed by the learning environment, the formalization of which increases the structural complexity.

4.2. Security, reliability and sustainability of the information and educational environment

Features of cognitive activity under conditions of information stress. The work (V. Mygal et al., 2018) considers the features of interaction in the "student – information environment" system. Attention is drawn to cognitive distortions, the degree of which depends on the stress resistance of the student. In particular, the consequence of non-complementarity of cognitive graphics methods is:

- limiting the potential of data mining and predictive analytics;
- the increasing complexity of machine and deep learning;
- the difficulty of selecting relevant information, which is due to the law "7 plus minus 2".

Therefore, in the extreme conditions of a pandemic, environmental and man-made disasters, the complexity and uncertainty of human-computer interaction increases (V. Mygal et al., 2020; O. Ilyashenko et al., 2021).

A non-obvious generalization. Safety (biological, functional and informational), reliability of information sources and their stability integrally reflect the concept of viability.

The connection between the processes of management and cognition in the evolution of the concept of Resilience, Dependability, Viability. In the development of the concept of viability participated:

- R. Ashby formalized the concept of viability (Ashby, 1947; Ashby, 1956);
- S. Beer built a formalized Viable System Model (VSM) (Beer, 1984);
- R. Espejo et al. have applied VSM to the needs of organizing complex systems in business (Espejo, 1989).

Each of them used certain principles of resolving contradictions by distributing opposite properties or actions in space or time.

Intuitive generalization. The complementarity and connection of the processes of control and cognition follows from the metaphysical principles of active reflection and cyclicity.

Human hardiness. From a psychological point of view, resilience as a person's hardiness is based on the vision of different ways of solving problems and the positive experience of choosing the optimal one (Maddi, 1968). S. R. Maddi described hardiness as:

- a characteristic of the personality, which is formed from childhood through certain interactions with the environment and is the key to stress resistance;
- an evolving trait affected by induced cognitive distortions;
- confidence in their functional health.

Hidden information about the vitality of a person contains small deviations, jumps and fluctuations in electrophysiological signals (G. Mygal et al., 2019; G. Mygal et al., 2020). Therefore, under extreme conditions, the concepts of "viability" and "resilience" are complementary.

Intuitive generalization. The vitality of a person in difficult conditions is determined by the spatial heterogeneity of information sources and the medium for its transmission.

4.3. Vitality and resilience of the digital environment

Complementarity of the principles of modern metaphysics. To identify natural relationships in the space of dynamic events, three key principles of modern metaphysics are important:

- the principle of connection between binary and trinity, which turns metaphysics into a single system of paradigms;
- the principle of fractality, in each of the selected parts (categories, beginnings) the features of all others are manifested;
- the principle of dual cyclicity, which reflects the evolution of the spatio-temporal order.

Complementarity of key principles follows from the principles of biomimetics, which confirms self-similarity. On the one hand, natural fractals and multifractals exhibit statistical self-similarity, i.e. self-affinity. On the other hand, the topological properties of space (its three-dimensionality) and time (its one-dimensionality) are connected with the dynamic structure of cause-and-effect relationships of real properties (processes, phenomena) of nature.

Generalization-conclusion. The relationship of the key principles of modern metaphysics in the topological space has a cognitive value.

Information interaction in extreme conditions. The complexity of information interaction is due to the spatial and temporal inhomogeneities of the digital environment, which arise under the influence of environmental and activity stress factors. At the same time, the analysis of the diversity of unrelated parameters, indicators and criteria from different subject areas turned out to be ineffective for predictive analytics. The connection of heterogeneity fields, on the one hand, is the main factor in reducing the viability of the SDS and the vitality of a person in difficult conditions. On the other hand, information about the viability and resilience of the digital environment is hidden in the structure of spatio-temporal relationships.

Therefore, in difficult conditions, the issues of unification of the means of receiving, processing and displaying information flows from each element of a dynamic system in one space become dominant. The work (V. Mygal et al., 2021; Protasenko et al., 2021) considers the problem of predicting the viability of a complex dynamic system based on a metaphysical approach to identifying the individuality of the functioning of its elements. It is shown that information flows of different nature in the topological space of dynamic events have similar dynamic structures.

Non-obvious generalization. The viability of the digital environment in extreme conditions is determined by external influences, and human resilience is determined by internal factors.

Development of mathematical modeling and its problems. Archaeologists, anthropologists and ecologists, studying nature, are experiencing problems of lack of information for digital modeling. Whereas architects, materials scientists, designers, etc., borrowing ideas from nature, build unique objects, create smart materials, etc. However, the development of mathematical modeling is limited by K. Gödel's incompleteness theorems (Gedel, 1930), which underlie metamathematics. As a result, in the theory of artificial intelligence there is a problem of stopping - there is no algorithm that allows you to give an answer about whether the calculation program will stop or not (Russel, Norvig, 2003). In other words, there is no program that could show whether the computer is looped or not. According to Godel's incompleteness theorem, for any complete system of axioms, there will always be statements that will be inconsistent and loop the computer.

Intuitive generalization. The excess and lack of information about the spatial and temporal distortions of information flows limits the unique possibilities of metamathematics.

Complementarity of metaphysics and metamathematics. For physicists, practice is the criterion of truth, and mathematicians argue whether it is possible to prove everything that is true. For theoretical physicists, mathematics is a tool, and for mathematicians, physics is mathematical models (examples). Before the digitalization of science, mathematicians solved problems with theoretical physics, and theoretical physicists created new approaches (methods) that turned out to be very fruitful. In the 21st century, the generality of methods, structures and technologies of computational physics and computer simulation increased the complexity of algorithms, which created global problems of the stability of the control of the SDS in extreme conditions. Following A. Einstein, the solution to these problems should be sought in the dualism of complementary principles of metaphysics and metamathematics. In our opinion, the key ones are:

- principles – uncertainty, additionality and balance;
- methods - structural, topological and cyclic;
- paradigms/concepts – order-disorder, balance-imbalance and symmetry-asymmetry.

Obvious generalization. The complementarity of metaphysics and metamathematics makes it possible to study the transition from the duality of change to the triplicity of conservation.

5. Cognitive space on a transdisciplinary basis

5.1. The universality of the concept of order - disorder

The concept of order in the natural sciences. Relations of the same type are different in mathematics, physics and biology. So, in mathematics, order is a certain system of relations, and its absence is disorder. In physics, it is a correlation (a system of relationships) between a group of observed events. The biological and chemical order can be defined as the dual order of structures and processes. Therefore, in knowing the world, we are looking for order, using scientific methods. However, the logical basis for the search for order is increasingly moving away from reality. We also see other events that do not fit into the measurable or modelable. Therefore, such events are expressed by signs, the correlations of which form something that cannot be measured. After all, the process of thinking is a process of pattern recognition (Haken, 1995; Haken, 2003). However, the digitalization of science is accompanied by an increase in the complexity of problems, which limits the possibilities of predictive analytics.

A. Einstein's generalization: "The significant problems that we face cannot be solved at the same level of thinking that we used when we created them" (A. Einstein, Calaprice, 2011).

The idea of order and heuristics. As the various disciplines developed, the idea of order gained more and more depth. Understanding means ordering images (impressions) that allows you to derive general ideas from them. The formation of a “bridge” between the macroscopic and microscopic approaches is promoted by the concepts: order-disorder, simplicity-complexity, structure-function. However, when moving from models to real systems, cognitive difficulties and new problems arise.

In design, architecture and art, the circle of natural colors according to Goethe (Goethe, 1970) is widely used, the theory of which he developed for 40 years and most appreciated. In the circle of natural colors, the duality of opposite colors gives a harmonious combination and contrast, and the trinity of colors located at the corners of a triangle (either basic or inverted) is perceived as not a harmonious combination. These and other laws of physiological optics have allowed the development of complementary heuristic models, which are shown in Figure 3 and Figure 4.

Intuitive generalization. Cognitive perception of colors is influenced by the natural relationship between structure and function, microstructure and macrostructure, dynamics and statistics, which has heuristic significance.

Key principles of modern metaphysics. Many natural connections are considered by modern metaphysics (Terekhovich, 2018). To study the functioning of self-organized objects in extreme conditions, three key principles are important, namely:

- the principle of connection between binary and trinity, which turns metaphysics into a single system of paradigms;
- the principle of fractality (self-similarity), which reflects the unity of the whole and the particular;
- the principle of dual cyclicity, which reflects the spatio-temporal order.

Their complementarity is manifested in natural fractals and multifractals, which, on the one hand, exhibit statistical self-similarity, i.e. self-affinity. On the other hand, the orderliness of the spatio-temporal structure is characteristic of natural dynamic fractals and multifractals (V. Mygal et al., 2020).

The human mind has three keys: a number, a letter, a note, which open the harmony of the real world, and the complementarity of these keys allows you to know, think and dream.

Intuitive generalization. The connection between know, think and dream allows you to create, invent and predict.

5.2. How to measure reality and unreality (virtuality)?

Cognitive flexibility. The development of IT has led to the growth of “digital editing”, which blurs the boundaries between truth and falsehood. Digital literacy in a broad sense implies the ability to measure reality and unreality (virtuality). An increase in the number of information flows and the complexity of their dynamic structure increases the cognitive load. It reduces the effectiveness of learning, which also depends on:

- influence of external and internal stressors on the process of assimilation of information;
- insufficient emotional tension in the classroom;
- cognitive aspects of perception, presentation and analysis of information.

All this contributes to the development of complex-systemic thinking in the learning process and the manifestation of hidden cognitive distortions. Information redundancy of the educational environment blurs the structure of relationships and causes spatio-temporal inconsistency.

An obvious generalization. The conservative organization of the educational environment does not take into account the individual cognitive abilities of the student, the development of which is the main factor in effective learning.

Hybrid learning models. The HyFlex format combines offline (synchronous) and online (asynchronous) learning to achieve desired educational goals. The Digital Learning 2.0 format integrates mobility, individual approach and group work. However, in these formats there are problems that give rise to contradictions. They are induced by the structural complexity of patterns, algorithms and programs that limit the possibilities of using IT and ICT in the information and educational environment due to new contradictions. Since each of the hybrid teaching methods successfully solves individual learning problems, the complementarity of approaches, theories and technologies in the transdisciplinary cognitive space is of the greatest interest.

Intuitive generalization. Local distortions of phase boundaries (contours, configurations) of signatures and patterns in a transdisciplinary cognitive space allow us to observe, compare and compare what is really commensurable.

5.3. Cognitive problems and metasciences

Key aspects of metaphilosophy. Critics of the theory of science often cite the words of Mephistopheles from Goethe’s tragedy “Faust”: “Theory, my friend, is dry, but the tree of life is green.” Three key definitions are important for the development of philosophical thinking:

- crisis definition (philosophy as an opportunity to overcome the crisis);
- methodical definition (philosophy for introduction to philosophizing);

- methodological definition (philosophy for the implementation of philosophizing).

In our opinion, the practical relevance of metaphilosophy is in its natural transdisciplinarity.

Therefore, for further research, the complementarity of the metasciences, which is based on hidden interconnections between them, is important. The asymmetry of direct and reverse transitions between metaphysics and metamathematics makes them informative. In the real world, mathematics is a tool for physics, and in the digital world, mathematical modeling of physical phenomena is divergent and creative. This asymmetry limits the development of these metasciences.

Generalization-conclusion. The complementarity of principles, paradigms and concepts on a transdisciplinary basis contributes to the development of cognitive abilities.

6. Innovative potential of cognitive space

6.1. Concepts of order in the metasciences

The development of biomedicine and biotechnology has opened up a whole range of new opportunities that allow:

- determine the relevance of transdisciplinary tools of knowledge and practice;
- choose the most effective mechanisms for converting research initiatives into practice;
- compare the private with the whole, which is typical for multifractal signals (time series).

Considered in the works (V. Mygal et al., 2016; V. Mygal et al., 2018; V. Mygal et al., 2020; V. Mygal et al., 2021), the reconstruction of topological 3D models from one-dimensional fractal electrophysiological signals made it possible to create a cognitive space on a transdisciplinary basis, in which the orderliness of information flows of various nature contributes to self-knowledge and self-regulation (see Figure 7).

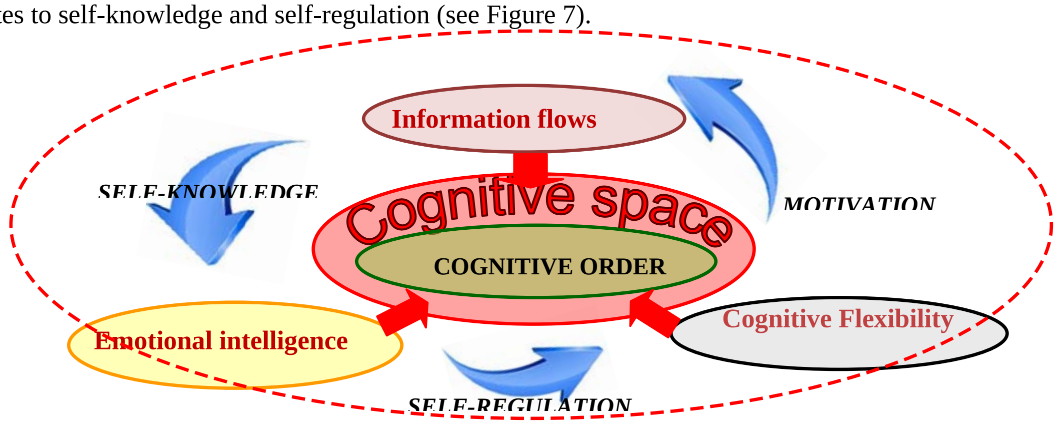


Figure 7. Convergence in the cognitive space.

Three interrelated components of emotional intelligence are closely intertwined in the cognitive space, namely:

- self-knowledge, as the ability to identify one's emotions when making decisions;
- motivation, as the ability to strive to achieve a goal;
- self-regulation, as the ability to control one's emotions.

Therefore, convergence is associated with the principles of complementarity and relativity, the complementarity of which contributes to cognitive flexibility.

It should be borne in mind that information flows are easier to interpret if they are processed simultaneously by the brain and heart. After all, only emotional intelligence allows you to go beyond theoretical knowledge and involves the development of understanding. Therefore, to overcome cognitive problems, it is important to study the dynamic similarity of information flows of different nature in the hybrid space of dynamic events. In this space, the spatio-temporal structure of feedback cycles is manifested, the universal code of which is hidden from us by nature (Prigozhin et al., 1993).

Generalization-conclusion. The presence of various cognitive resources in the information and educational environment simplifies self-knowledge, self-regulation and motivation, which contribute to the formation of emotional intelligence in the learning process.

The universal code of knowledge. The relevance of studying the evolution of the real world is supported by the integration of various methodologies, methods and technologies, which are based on universal principles and many fruitful ideas. We have identified three key ideas: 1) A. Einstein on forced transitions in a non-equilibrium environment. 2) G.

Haken on the principles of brain functioning. 3) I. Goethe on the transformation of the temporal duality of opposite colors into the spatial trinity of colors. Based on the complementarity of these ideas, we have created a universal cognitive model of self-balanced process control, based on three key principles of metaphysics (given in subsection 5.1). Cognitive models of self-management by coupled cycles of action and reaction are shown in Figure 8 (models a., c. and c.).

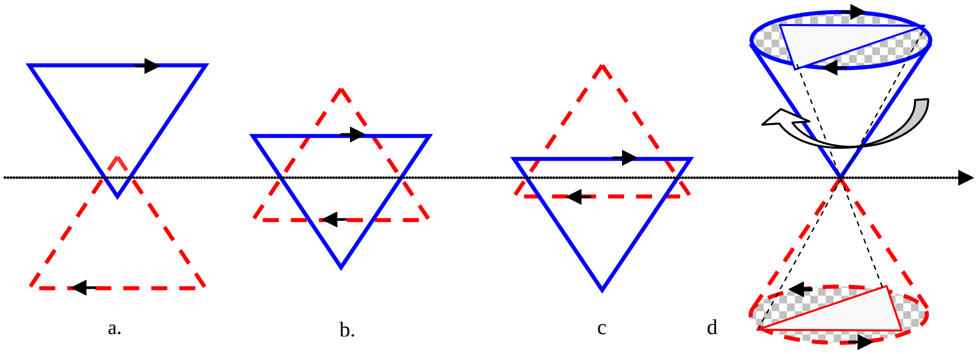


Figure 8. Cognitive models of self-balanced control of processes of different nature.

In the figure, conjugate cycles are highlighted in blue and red. At the same time, in the action cycle, the processes proceed clockwise, and in the counteraction cycle, in the opposite direction. Cognitive models (a.), and (c.) display dynamically unstable phases of cycles, and the structure of the model (b.) displays the phase of the dynamic balance of conjugated cycles, which looks like a star of David. The cognitive 3D model of ideal control is presented in the form (d.). In the work (Mygal et al., 2021) it is shown that the model (d.) can be synthesized using the superposition of two Sierpinski fractals, as well as a Koch snowflake fractal and an antifractal.

Generalization – hypothesis. The Star of David is a universal code for the knowledge of evolutionary processes in nature.

6.2. Augmented reality

Hybrid methods in education and science. The works (V. Mygal et al., 2016; V. Mygal et al., 2018; V. Mygal et al., 2020; V. Mygal et al., 2021) consider the cognitive aspects of the hybrid visualization of analog and digital information, which made it possible to create a cognitive space on a transdisciplinary basis. The convergent approach promotes the exchange of ideas, methods and technologies between educators and scientists of different specialties. In general, the cognitive space, hybrid technologies and extreme principles of natural science allow increasing intellectual capital by:

- combining elements of different teaching methods (transformational, machine learning, etc.);
- creating a hybrid environment (platform) for dialogue between students and teachers;
- innovations based on augmented reality and digital twins.

Augmented reality and digital copies in the cognitive space create qualitatively new opportunities for design, furniture interior, bionics and an integrated approach to the formation of the color climate of the object environment, which are given in the works (S. Mygal, 1999; S. Mygal, 2012; S. Mygal, 2014; S. Mygal, 2017).

Key takeaway: Digital twins in 3D cognitive space inspire and stimulate creativity.

7. Conclusions

The digitalization of various subject areas and sciences is accompanied by an increase in the complexity and uncertainty of information flows of various nature. The dominance of two directions – theoretical (equations of mathematical physics, etc.) and computer engineering (integrated technologies, etc.) does not allow solving the problems of science and education in extreme conditions (pandemics, man-made and environmental disasters). The critical thinking of the authors of the article was formed in the process of solving real problems of technological heredity in reasonable materials, the human factor in ergonomics and engineering psychology, as well as in the theory and practice of design. Critical thinking has allowed us to:

- formulate generalizations – obvious, non-obvious and critical (intuitive);
- create a natural cognitive space on a transdisciplinary basis;
- offer a convergent approach to solving real cognitive problems.

In the cognitive space, the complementarity of the three key principles of metaphysics, the duality of metamathematics and the trinity of modern metaphilosophy were manifested. Features of direct and feedback links in each metascience and between them determine new information challenges that are induced by the digitalization of education and science. New possibilities of the convergent approach are considered, which are based on:

- technology of hybrid processing of analog and digital information;
- technology of natural transformation of information flows into topological 3D models;
- tools for structural and functional analysis of signatures and cognitive patterns.

All this simplifies the exchange of ideas, methods and technologies in the information and educational environment. The proposed tools make it possible to develop integrative indicators and criteria for the viability of complex dynamic systems, including human resilience. This is important for quantifying intellectual capital and predicting changes in human capital under extreme environmental and other conditions.

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