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The digital school is ushering in a new era in the development of education. The nature of pedagogical relations, teachers’ socioeconomic status, educational content, technologies, education quality management, and learning outcomes fundamentally change.An environment is being created for the full implementation of the competency-based approach in basic education. With that, the digital school retains continuity with the existing education system, making the transition fast and realistic.

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Introduction

In 1995, Nicholas Negroponte introduced the notion of "digital economy"into scientific circulation. In the same year, the World Wide Web acquired its modern look: network providers began to route all the traffic, the Internet became the leading provider of information, independent of any companies, and a stand-alone virtual reality. A new economic era based on digital technology, e-business and commerce, and electronic financial settlements has emerged.

The digital economy occurs in the global digital reality — the Earth's informosphere. It creates, accumulates, transforms, disseminates, and applies information that is instrumental in modern industry. New opportunities to control time and space are opening up for the economy — the opportunity to work online in real-time across the globe.

The fundamentals of the digital economy are technologies of the Fourth Industrial Revolution: the Internet, artificial intelligence (AI), blockchain technologies, neuro-and biotechnologies, virtual and augmented reality, additive manufacturing, multi-dimensional printing, etc. However, the economy is not only a matter of technology. It is also about how social relations are historically shaped through production, distribution, exchange and consumption of goods necessary to sustain human life and development. At the time of any historical shift from one economic formation to another, cultural codes, value-based activities, forms of social consciousness, the world view, the content, modes and techniques of learning, man's attitude to work, life, and the world at large change.

The formative processes of the digital economy invariably initiate profound changes in social relations, consciousness, and activities."The age of new technologies — if its development is masterminded by sensitivity and responsibility — is going to become the advent of a new cultural renewal that will let us feel part of a single whole: a truly global civilization… It will propel humanity towards a new collective consciousness and moral reasoning based on a shared sense of destiny.1Ultimately, all technological and social changes should give us new insight into and rational answers to the age-old question, more accurately reflecting the essence of our existence in the world: «What is it to be human?» (Klaus Schwab). The question itself and the collective search for answers imply that the economy going digital is no longer limited to the latest technologies but also embraces social relations, including education. Without deep modernization, any further development of the new economy is difficult. "Technology and society are changing and shaping each other. We are shaped by our technologies as much as they are the product we create... Technologies are solutions and products that develop through the social processes with entrenched priorities and values."[2]

Education has always played a pivotal role in economic activity. n the context of the digital economy, its importance is multiplied by the fact that it provides the initial accumulation of its main productive resource — human capital — by building and enhancing, continually and successively, basic and professional competencies. Education, along with technology, must become a key driver for the new economy. Today, incredible as it may seem, it is the major constraint of further economic development.

Human capital consists of abilities to perform productive activities and includes knowledge, skills, experience, values, motivations, relations, modes of thinking and other components of consciousness and behavior. These abilities are already shaped at the level of basic education and develop throughouta lifetime.

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[1] Klaus Schwab, Nicholas Davis. Shaping the Future of the Fourth Industrial Revolution. — M. 2018. — p 14.

[2] ibid pp 62-63

The existing school system had been established to meet the needs of the industrial economy well before the digital age. It has not changed substantially since then. Informatization, or digital tools, has given rise to learning opportunities but changed nothing on a deeper scale.

An interactive whiteboard replaced a wooden board with chalk and a cloth; a personal computer took the place of the projector and calculator; the content of a paper textbook was duplicated electronically. The Internet opened access to unlimited volumes of additional information. However, the education content has not changed. The teacher's attitude toward his work and the learner's attitude toward the learning process have not improved. The standards and methods of teaching are at the level of the early 20th century. No invigoration of pedagogical relations has occurred. Motivation for learning activities is not increasing either. This poses serious risks for the digital economy.

The traditional industrial-typeschool continues to function in a fast-evolving digital economy, shaping the necessary abilities for an industrial society. Traditional schooling is obsolete; it does meet neither the expectations of teachers, students, parents, nor the needs of the State and business. There is a fundamental contradiction between the traditional education system and the new digital society. As it is today, the school challenges all the levels of social structure, hindering the development of socioeconomic relations as well as the modes of thinking and performance consistent with the digital economy. Let us consider this contradiction by comparing the key characteristics of digital economic activity with the school's total workings.

Motivation for Productive Information Activities. The digital economy — the basis of the information society — produces information objects in the broadest term. Information is its key resource. The educational subjects — the teacher and the student — also work with information objects: knowledge, concepts, models, theories, etc., which make up the education content. However, schooling does not shape or strengthen a sustainable motivation for cognitive activityin most students over the years. Learning is not interesting, knowledge is not self-worthy. A student studies to get a high grade, earn praise, avoid punishment, pass an exam, get a good certificate, and enter the university. He finds the goals of education beyond its content.

Creating a strong positive motivation for learning with the digital has never been, nor is it among the traditional schooling priorities. This is due to the system of social relations prevailing in industrial society. Under the social division of labor, together with intellectual and manual labor to wither away, most people perform monotonous work throughout their lives. This kind of work seldom has any value itself; it is largely done for a living. The Industrial Age school was essential within its framework. It builds a human readiness to integrate into the standard work processes and perform monotonous tasks, often devoid of internal personal meaning.For the industrial economy, the motivation for learning is not a priority since it does not massively affect the success in economic activity.A person could be a mediocre student at school but a good worker and successful entrepreneur after graduation.

The human activity begins with a motive and is entirely mediated by it. The industrial society did not require the school to shape up the motivation for productive information activity. This motivation is crucial for the digital economy. If a man, starting from childhood and later as a teenager and a youth, the most sensitive times of man's life, does not consistently develop the ability to independently, creatively, and responsibly work with knowledge and other socially significant information objects, the digital economy loses its main productive power — a creative and competent worker.

Capital and Wealth. In the classical and most general definition, capital is the resources that are used to create wealth. It is one of the top three factors of production, along with land and labor. In an industrial society, tangible capital, external to the person, dominates: money, buildings, cars, etc. Human capital plays a leading role in the digital economy. It consists of knowledge, experience, competencies, personal and professional human qualities, social relations and mounts up through the shaping and developing a personality, in fact, from childhood.

Wealth is the basis of capital. In an industrial society, it consists mainly of material values that belong to man by virtue ofa particular social status, often being lost when the status changes. The information society is dominated by a different type of wealth — internal, inalienable from the individual. It includes the processes and outcomes of education and self-education, the system of values, life and social priorities, a personal level of culture and openness towards other cultures; physical, mental health and spiritual welfare; life experience, the experience of professional creativity, social and interpersonal interactions, forms of reasoning and modes of thinking, and much more that makes up the content of a person's life.That part of inner riches that helps pursue practical, social, professional, and other objectives to create particular benefits becomes human capital.

Traditional schooling does foster neither the development of human capital nor the formation of individual inner riches. Strengthening health, awareness and acquisition of values, formation of a holistic modern worldview and constructive social relationships, development of independent thinking, accumulation of experience in productive activities, the discovery of abilities and talents, active search for one's "I" in the world, and many other forms and ways of support for the student personal growth lie far beyond the real potential of educational programs and are at best declared when setting general teaching objectives. The primary, and in effect the only, function of the school is to transmit objective knowledge to students and build their skills and abilities. The connection between the content of education and the life of the individual is not pedagogically revealed. Traditional schooling ignores the student's inner world. The student's attitudes toward school, learning, teachers are formal, based on standards, and strictly regulated.

And yet it would be unfair to accuse the current school of being inhumane to man and ignoring the content of his life. It only fulfills the tasks it was historically created for by the industrial society based on tangible capital flow. In all its ways, the school's tenor hinders the growth of inner riches that the students could use as their human capital. That is the way an industrial economy works. Having received an education, a person enters the market of tangible capital where his inner riches have no value. He sells out his workforce, preferably skilled. Traditional schooling deliberately impoverishes a person. From the standpoint of industrial society, it's humane. Otherwise, no living would be possible in a society where selling out one's workforce was the only way for the majority to earn a living.

The Model of the "Creative Man". The human model is an abstract concept reflecting human activity, reflecting the way of human life that dominates in a particular social environment.The model of a "homo economicus, or economic man" dwells at the heart of the industrial society. It emerged at the advent of the Industrial Age when simple physical labor prevailed, and the exchange of commodities was the leading form of social relations. The mechanistic world landscape partly conditioned the model: in economic relations, people are like physical objects that move in society and collide with each other,and the strength of the impact of one individual on others is determined by his "mass," i.e., material position.

The information society is in need of a different model — the model of the"creative man". Creative activities and constant information exchange are key parameters of the model. For the “economic” man, existence is about possessing tangible wealth. For the creative man of the new age, existence is about being a person who matters to himself and othersbecause of inner riches realized through productive and creative activity.

The meaning of the “economic” man’s being is to abound with things, among many others. He takes possession of the things of this world to boost his social value. The raison d’être of the creative man is to be and become many things in his own life, transcending the material world, multiplying his inner riches, and creating benefits meaningful to other people. Both models are of economic nature and implemented in an environment dominated by physical or informational capital.

A creative man in the digital economy is an economic subject capable of transforming part of his inner riches into a social productive force — human capital — and creating new information objects (in broad terms). Capital is the value used to generate surplus value through economic activity. Human inner riches are determined by their “value”— their importance, value to the man himself and others. However, at this point, they do not yet turn into capital. Value turns into capital when incorporated into the actual production of goods and their voluntary exchange. For example, money in one’s pocket has its value, but it is not financial capital. In the same way, inner riches may have value for man and other people, but they do not yet turn into capital. If someone has vast knowledge, experience, competencies, etc., but does not use them to produce goods or invest in productive activities, they drive their inner riches out of the digital economy. To be a real subject of economic relations in the information society, man must create new information that is valuable for people and, therefore, has value.In the digital economy, creativity implies that man uses his human capital to produce goods and gain surplus value to the inner riches invested in creating information. A non-creative man cannot be a productive subject of the digital economy.

Enhancing the student's creative abilities and empowering his creativity as a sustainable personal quality lies on the periphery of the pedagogical tasks of the traditional school and beyond its real teaching opportunities.All attempts to give the learning process a creative character are thwarted by the seemingly immutable and absolutely reliable assertion of classical didactics that students do not create new knowledge but only assimilate what was once created by others.In an industrial-type school, under the transmissive learning based on knowledge reproduction, the student cannot create anything objectively new according to the laws of this training itself.In industrial society, creativity dwells in science and arts — there is no room for it at school. Creativity can be developed at universities, in scientific laboratories but not at schools. Schooling, still employing Industrial Age practices and processes, does not fashion human creativity — the ability to employ human inner riches and create new information objects with a real surplus value (value to others).

Individualization. The industrial economy is based on large industrial enterprises focusing on technological operations for manufacturing material goods. Such enterprises have several typical features: rational (scientific) organization, labor specialization, labor cooperation, line production, conveyor assembly method, product typing, etc. Diversity is managed through unification, i.e., by eliminating excessive diversity of elements, solutions, processes, and subjects of labor, by bringing all components of production to uniformity. For the industrial-type activity, man matters as a skilled performer of standard production operations. That ensures the interchangeability of workers. On the contrary, the digital economy encourages the development of uniqueness, personal qualities, and creativity. Otherwise, inner riches do not generate, and the value of human capital drops.

Another reason for focusing on individualization in the information society is the very nature of information itself.

According to W.R. Ashby's Law of Requisite Variety, the information contained in a particular system is expressed by the number of its non-identical elements. If a system consists of N number of non-identical elements, the amount of information contained in it will be equal to N. If the elements change over time, so does the amount of information. According to this theory, individualization is one of the key economic factors in the information society where information is a pivotal productive resource, and human capital is the main driver of the economy. Each society member's bright personality, the diversity of their inner life and social relations shape the social structure with great opportunities for generating, exchanging, and creating new information. The more people are alike, the less social diversity is to be found in society; therefore, as an information society, it is less productive and creates fewer opportunities for the development of digital economic relations.

The actual mass school's workings are not conducive to the development and self-realization of students as subjects of their own lives and activities. Individual approach is proclaimed everywhere, but the humanistic values of many teachers, including their professional ethic to work with each student in keeping with the student's abilities and needs, cannot resist the total standardization of educational content, objective, non-personal knowledge, the very system of mass education based on the "golden rule" of classical didactics. It was formulated by John Amos Comenius at the dawn of the Industrial Age: «To teach everyone everything in the same way».

Networking for Activities. The digital economy can operate worldwide due to a global network that integrates networks of various types: production, trade, computer, education, etc. The bureaucracy is replaced by information workers who do business online around the world in real-time with no spatial restrictions. Networks are becoming units of economic activity. Networking requires a swiftly established order, flexible thinking and behavior, continuing innovation, and effective time management.

The principle of the networked organization of educational activities is poorly implemented at schools. The school remains a bureaucratic organization featuring the industrial society. The learning process is confined to the school, just as the production process is carried out within an individual enterprise. Both processes imply a unified sequence of actions performed by students (in production — by workers) and overseen by teachers (in enterprises — by technologists and engineers). Students rarely interact with one another in classes, except when non-standard lessons are held: a lesson-dispute, a business game, etc. As a rule, they receive an assignment, perform it individually, and report back to the teacher. Social networking for educational purposes is carried out locally, occasionally, in an experimental mode; it affects neither the nature of the learning process nor the methods and modes of training.

Meanwhile, the modern child is an active and competent participant in many social networks despite his age. But they have nothing to do with his learning activities.As a result, over the years, he develops a strong perception that the network logic does not apply to learning activities, that networks are necessary for communication and entertainment while he should systematically work with knowledge in the usual bureaucratic system. Developing the culture of networked communication, thinking, and productive information activity is beyond the traditional school workings.

Participation in Managing the Digital Economy. The key to economic activity is information, knowing how to use resources to achieve goals. In an industrial economy, information is monitored by producers. In the post-industrial and digital economy, large databases are also operated by suppliers and buyers. They engage in manufacturing as information holders, set up objectives, invest knowledge and money. In the new economic relations, the buyer is one of the management actors in the production of material values. He ceases to be only a consumer and becomes a partner and participant in economic relations. For modern companies, orders placed are more important than sales, and their employees and customers are network-connected business partners and co-owners of production processes.

The modern school, still employing Industrial Age practices, shapes a passive consumer of ready-for-use knowledge and simple services. Even in educational organizations where profile education is practiced, and students are free to choose both subject matters and the level of complexity, patterns of productive behavior characteristic of the information society are not conditioned. Students are given a limited right to choose "off-the-shelf" content, just as a shopper can choose a product only by the price list. For developing co-management skills in the socioeconomic processes of the information society, the learner must be able to influence the content of the educational process and assimilate the learning material that he himself is capable of partially creating. In the digital school, the learner co-creates and co-manages educational content on an ongoing basis. This is necessary for fashioning a competent subject of the digital economy. But this idea does not fit into the structure of traditional teacher thinking, and its implementation confronts the running system of development, delivery, and assimilation of the learning material.

The existing industrial-type schooling is a powerful deterrent to the further growth of the digital economy. It builds a persistent negative motivation for productive work with knowledge in the period of life when the personality traits are laid, does not create an enabling environment for the development of inner riches and the initial accumulation of human capital. A non-creative man is not productive in the digital economy and, therefore, deprived of its opportunities and benefits. Mass education averages a man, standardizes man's thinking, behavior, outlook, and social relations. On the contrary, the information society is a society of unfolding diversity. Continuing to shape the man of the industrial civilization, the education system brings about deep conflicts in the learner's self-attitude (he is not readied for independent, productive and responsible activity in the information society), in the economy (it fails to develop without sufficient human capital), in public safety (access to the latest digital technology with incompetence and low levels of personal responsibility leads to devastating consequences). The digital economy makes fundamentally new demands on the quality of education, its content, modes and methods, the activities of its subjects, and on the school's tenor. It makes the moral aging of traditional schooling fast and obvious, fostering a growing need for a new system of basic education, with modern digital technology offering a real opportunity to create a new school.

Part I. Cultural and Historical Context of Digital Education

Chapter 1. Historical Development of Information Activities

1.1. Notion of Information

Information is a fundamental notion in the field of the digital economy. It is the focus of twenty-first-century thinking. Norbert Wiener, the founder of Cybernetics, defined it as follows: "Information is the designation of the content received from the outer world in the process of our adaptation to it and the adaptation of our feelings to it."[3] This classic definition denotes three critical aspects of the information activity.

• We acquire information from the outer objective world. Consequently, it exists independently of man, as does the world itself.

• "Information is the designation of the content," i.e., the content processed by signs. Specialized sign systems or languages are historically formed or artificially created for information handling. Information processing is impossible beyond language activity in its broad sense.

• Man and society "adapt to the outer world content" by working with information. Man in the process of learning, socialization, and work, society in the course of its cultural and historical evolution, both keep moving to a better correspondence between the ability to work with information, the outcomes of this work (knowledge, culture, technology), and the information

[3] Norbert Wiener, Cybernetics: Or Control and Communication in the Animal and the Machine; or Cybernetics and Society/ 2nd edition. - Moscow, 1983. - 344 p

that fills the universe. Thinking and activities lead the way to the completeness of knowledge (information) about the world.

Information objectively exists in Nature as one of the three fundamental components of the universe, together with matter and energy. As Norbert Wiener said, “Information is information, not matter or energy.”[4] Energy drives all existing objects, including the universe itself. Energy is a process. Matter creates the interior space of the object and the external space where objects interact. Matter is a form. Information is the order, the law governing the universe, the harmony that is visible throughout Nature. Without information, the universe would be chaos. It owes its perfection and the passage of time, measured for life and man, to information that grows as the universe evolves. It is information that makes our universe organized, harmonious, and perceptible.

Information *— is the order objectively existing in Nature and reflected in the processes of cognition.* It is created by man’s and humanity’s activities. This definition rests on the physical and linguistic interpretation of information.

In physics, there are two known definitions of information — quantitative and qualitative. We can calculate and quantify information because it is a variety of sets (W. R. Ashby). As to its qualitative characteristics, another definition applies: information is a degree of order and organization of material objects. The object of a more complex nature contains more information, and, on the contrary, a simpler kind of object is less informative. In this physical sense, information opposes entropy — a degree of disorder or randomness in the system.

The physical notion of information sets up its strictly objective nature (i.e., its existence regardless of a human being), while its linguistic idea lies within the scope of human activity. In the science of languages and speech activity, information

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4 Ibid

is messages, data, perceptions, concepts, knowledge of something. Languages (linguistic signs) are instrumental in making, encoding, and decoding them, and texts (linguistic sign sequences) are the forms for information storing and transferring. By speaking and thinking, man creates linguistic signs sequences: words, sentences, messages, etc.

The linguistic and physical approaches supplement each other. Any data can be stored, conveyed, or perceived only as sequences of signs. Texts (messages) contain information. To compose them, one has to arrange linguistic signs in a particular order. It is the order that attaches meaning to linguistic signs and makes a text informative and comprehendible. Any violation of linguistic signs sequence, in the slightest, either deprives the text of its content, makes it uninformative, or attaches a different meaning to it. And so says physics: information is a sequence of material particles, elements, objects, processes, states, etc. These sequences exist in Nature. Physics and other sciences describe, study, and reproduce them employing their languages. Information is the order of arrangement and changes in the material elements in space and time. And it does not matter at all of what kind the elements are. The order of both planetary movements and letters in a sentence that the child writes in a school notebook implies information.

Information is unevenly dispersed and concentrated in some parts of the universe. Its volumes are much higher in organized clusters of celestial bodies (as illustrated by our Solar System) than in interplanetary and intergalactic spaces. The highest concentration of information within the observable universe is on the Earth due to the emergence and evolution of organic and intelligent life. The human race produces, stores, and accumulates information in astonishingly great volumes and at an escalating speed in actual time and visible space, gradually spreading it into the near and far parts of the universe.

The information generated by humanity is a further extension, elaboration, disclosure, and enrichment of the information that objectively exists in physical and social nature. A unique feature of information, not typical of the two other substances of Being — matter and energy, is its capability to separate from its physical carriers. Thinking is, in fact, the process of separating information from the material objects that generate it. In a cognitive process, the sequences of signs/symbols (texts) reproduce the orders objectively existing in Nature. These sequences (texts) shape the culture as a semiotic space for information to be accumulated and transmitted over historical times.

Humans not only reproduce objective information existing in Nature. They also create new orders that have not existed in the universe before them. In this vein, creativity and material production play a pivotal role. New meanings, which are formally nothing but new sequences of linguistic signs, emerge through creative activities. In the work process, new material orders are created from the material elements through the use of matter (tools) and energy; they emerge as artifacts increasing the volume of information in Nature. From a physical standpoint, any human activity is informational because it creates new orders and brings diversity to the world of matter. Whether we write a letter, talk, read a book, travel, work, study the starry sky — we create new information accomplishing these or other forms of pursuit. Information activities determine the meaning of human existence. Man exists in the universe to perfect its organized nature by expanding the volumes of information it contains.

1.2 Concept of Information Revolutions

Human history is driven by the need to develop information activity and unleash its potential. The three most important areas of this activity are storing (accumulation), exchanging (communication), and processing (creation) information. When one area changes qualitatively affecting the other two, the change of historical epochs in human civilization occurs. We will call this change the information revolution. During the first information revolution, a human community emerges. In the modern age, we are participants in the fifth information revolution, which opens up radically new information handling opportunities for humanity. Let us consider all five information revolutions Let us consider all five information revolutions in sequence.

The First Information Revolution.

Information activity widespread in the plant and animal kingdom is an objective prerequisite for human activity. All organisms receive information from the external environment, store and process it through their bodies in their nervous system, and pass it on to each other. Information is objective and circulates throughout Nature. Information processing (information activity) is not an exclusively human feature. Highly organized animals use simple languages — information encoding systems that they understand, communicate with one another; their central nervous system is well developed and capable of complex information processing. Language and possibilities to store and communicate information are not sufficient conditions for human activity.

A historical transition from organic-based information activity to a properly human way of information handling and, with it, to the human community occurs with a revolutionary change in information storing (accumulating). All organisms, and even inanimate objects, can store information in their body (physical form). This is also inherent in man, but it is not what makes him human. What does is the ability to accumulate high volumesof information through artificially created objects explicitly designed to store data. Human history and information activity itself both begin with exploiting this ability.

In primitive society, all the functions of a highly organized animal pack are preserved. Each pack member accumulates and processes information in their body, communicates it with physical organs. Also, out-of-body forms of storing vital data take on greater and greater importance. These forms evolve along three main lines: the cult of the old, traditions, and artifacts.

There are no cases in the animal world when aging specimens, no longer able to procure food independently, are taken under the pack's protection. This applies only to human society: the elderly are protected, nurtured, revered, entrusted with critical matters. They accumulate lots of information during their relatively long life and, therefore, are keepers of order, certainty, and the structured nature of the tribal life. Older adults can retain and convey information about their own lives and the life of the entire tribe or the environment. Being well-informed, they implement their knowledge to set the necessary order of things and relations: they know how to make tools of labor and hunting, perform a ritual, establish a connection with the spirits of the dead, to deal with a situation, etc. They retain information mainly in their own memory as animals. However, a revolutionary new factor uncharacteristic of the animal world emerges. Regular assistance and other people's care help to accumulate information. The community members use the memory of the elderly as an organic repository of vital information.

Traditions and artifacts are, on the contrary, purely inorganic ways of information amassing. Tradition refers to something that an individual does not create, is not his own idea, that exists objectively, independently of him, and is passed down from generation to generation. Collective human activities like rites, rituals, holidays, and others keep the tradition alive. It is of high information capacity and can include religious beliefs, complex images, and symbols. Traditions fashion the collective community memory as strictly ordered human actions and pass them down from generation to generation.

Artifacts, i.e., human-made objects, are crucial for an inorganic way of information aggregating. Among them, symbols play a pivotal role as objects-products of human activity that denote other objects. Tools of the trade, clothing and jewelry, household items, works of art, other products are also artifacts that hold vital information. They all contain valuable data for man.

The first information revolution fundamentally changes the way information is stored. This is where the most ancient history begins, including the following stages of human development: an Australopithecus (ape-man), a Homo habilis ("handy man" who made primitive tools), a Pithecanthropus erectus (Java Man who used fire), and a Sinanthropus pekinensis (Peking Man, aka Homo erectus pekinensis, who was dressed in skins and made stone tools). When information accumulates out of the primitive man's body in relatively high volumes, a new way of information handling becomes a must. The next information revolution meets this historical challenge.

The Second Information Revolution.

It creates a properly human way of information handling based on signs and sign operations and triggers the emergence of an articulate speech. The rudiments of articulate speech start developing in the Neanderthal; speech fluency begins about fifty thousand years ago and is characteristic of the modern type — Cro-Magnon Man.

The second information revolution takes place at the historical turn from artifacts to signs as central tools for information handling. The artifact is the simplest and physically massive storage medium. It represents an artificially made object containing essential information about another object and all information about itself. For instance, a tool. It contains information about the methodsof making it, about the person who made it, it can be nicely embellished and give a genuine aesthetic pleasure. And yet, the main purpose of the tool is to use it in relevant work activities. Another example is rock art, which can tell us a lot about the way of life of primitive people. But the purpose of its creation was different. The rocky image of successful hunting played a crucial part in the magical ritual of preparing for it. Each artifact has a particular implementation. Its importance and material form are self-valuable.

Unlike the artifact, the sign has a different nature. It also denotes a different object and has a physical shape. However, its material fill-in is not essential. Its content denotes something existing outside the sign. This denotation itself presents the meaning (content) of the sign, which has no other meaning. The sign is an artifact with no content of its own, making it exceptionally worthwhile for information processing. The sign entire content is taken out of its boundaries, which allows for arranging signs in sequences, creating and sharing verbal acts.

The spoken word becomes a form of storing information besides artifacts. But its core value dwells in opening up completely new opportunities for information handling. For composing a verbal act (arranging the signs into a meaningful sequence), specific rules are necessary, known both to the one who stores the information in the speech act and to the one who retrieves the same piece of information from it. Articulate speech is a process of sign-operating by the set rules.

The heart of the second information revolution resides in the advent of rules for working with information stored and accumulated out of an organic body. Initially, speech activity establishes rules, but their value extends far beyond the language.

The rules for linguistic signs define all other rules for new orders and varieties in the world to arrange. The ability to work with linguistic signs by the known rules and lay down new rules for sign-operating gives rise to practical object-oriented activity and brain-work.

The Third Information Revolution.

The historical evolution of articulate speech, thinking, and labor and a growing number of voice messages in the diversity of their meanings initiate the third information revolution. Like the first one, it aligns with a radical change in information storing (accumulating), but already on a new basis. The first information revolution lays the groundwork for information stored in artifacts, the third one — in written texts.

Messages (spoken texts) are more informative than artifacts. Texts are easily connected, thus accumulating high volumes of information. Their differentiated sign structure ensures the accuracy and completeness of recreating the outer world's orders and diversities. The artifact does not have such a capacity; it is bulky and static. However, compared to messages, it has one big advantage. With its robust material base, it can store information for a long time. A linguistic sign spoken out is delicate: the word spoken does not live long. The advent of writing historically resolves the contradiction between the new information power of the text and its short life limited to the actual time of oral speech.

The third information revolution leads to the birth of culture, the State, urban life, the education system, the division of labor, and the advent of social classes and strata. It actually creates a human civilization and crowns ancient history. Written texts are just as long-lasting as artifacts, but they offer radically new options to accumulate information. Connecting, they build a culture, i.e., a complex textual reality, a world of signs or "semiosphere" (Yuri Lotman). Culture forms a "second nature" (Schelling), which reflects in its texts the first nature (objective, natural, existing before and independently of humans). It can reproduce the whole world, all the orders, and diversities of the universe. Culture can also reflect itself. Its information capacity theoretically has no limits.

The large potential for accumulating informationcombined with the progressive methods of processing it — articulate speech and thinking — is at odds with the primal social organization based on blood kinship.Culture and its constituent written texts are created through information activities, and this activity itself is possible only in society. The indigenous community is small, segregated, and its social relations focus entirely on its members' survival. It is not suitable for the rise of culture and can process rather low volumes of information. The necessity to implement new ideas of the emerging culture calls forth a historical transition from the indigenous community to a people and the State — the new actors of information evolution effectively supporting the rise of their cultures. The epoch of the primitive communal system did finally cease to exist.

An ethnic group (a people) is a broad social group sharing language, collective historical memories, values, religious beliefs, economic life, ancestral territories, mentality, and other factors that generally define material and spiritual culture. Culture ensures the unity of an ethnic group supported by the state structure. An ethnic group is a new type of community and culture-bearer. The cultural content defines its collective memory, social relations, values, goals, and the nature of activities. Culture turns heterogeneous masses of individuals into a single people. It is a culture that forms a society sustainable over time, consisting of millions of people who freely communicate, understand, support each other, enrich themselves with knowledge and practices, and receive further benefits necessary for life. In turn, any ethnic group lives to ensure the existence and evolution of culture, accumulate, store, transmit, and process information for collecting new data within the boundaries of their language, history, and traditions.

An ethnic group, as a subject of cultural evolution, needs its own state system. The need for it historically stemmed primarily from the “manual” way of creating and processing written texts.”Manual” cultural reproduction implies that texts are written and copied on an analog basis, either rewritten by hand or printed using typographic techniques. Texts are physically collected in specific places (libraries, schools, universities, archives, bookstores, etc.). They cost a lot of money and are not available to everyone. Their way from the author to the reader is a long, complex, and expensive process. From the invention of writing systems circa 5000-4000 BC and throughout the 20th century, any effort to write, store, deliver, handle texts was complicated, time-consuming, and required continuous human effort. Tools for cultural pursuits are a pen (pointed stick, stylus, pencil, ballpoint pen, typewriter) and paper (papyrus, clay tablet, parchment, waxed board). Texts were written and rewritten manually. The printing press arrival reduces the cost and speeds up the publishing process, but does not make it easier to work with them. Working on texts consists of writing, processing, distributing, reading, analyzing, searching for information required for writing new texts.

The complexity of information handling translates to the specialization. There come those who devote their lives to working on texts (scribes, oracles, philosophers, priests, lawyers, officials, scientists, artists, etc.) and those who produce material goods. Material and information production become separated. Social stratification and the social division of labor ensure high-level cultural dynamics. For this division to start and stand, a special organization of social force — the State — is required. An ethnic group can exist without the state structure, but then its cultural evolution shows no intensity.

The Fourth Information Revolution.

Fundamental changes in the way of storing and processing information provoked the three preceding revolutions. Nonetheless, the way of its dissemination hardly changed from the earliest times. A horse remained the fastest delivery, and the volume of information transferred was rather low. The volumes of information to convey dropped sharply as the speed and distance increased. For example, a watch fire could pass on scant information (just one bit in a modern measurement system).

From the second half of the 19th and throughout the 20th century, transport and communication technologies emerged and developed. Telegraph, radio, and rail traffic appeared, followed by telephone, television, satellite communication systems. Highway service, air access, and sea links were developing rapidly. The speed of transmission of information went up sharply, with people and goods, both being data carriers, moving around much faster. Meanwhile, the cost of these services went down, eliminating spatial and temporal constraints in relationships between people, social and economic entities. The ways of information transmission and data carrier movements were changing radically.

Vast volumes of information that culture historically accumulates combined with the advancing communication and transport technologies led to the information explosion in the second half of the 20th century, i.e., a decisive boost in speed and volume of information production not only inside national cultures but also across the planet. With that, information processing through articulate speech deeply attached to individual thinking remained traditional. Verbal and cogitative human activities remained a leading technique for information handling from primitive times. However, as soon as culture accumulated big data, with communication technologies ensuring their relatively rapid delivery, the human brain turned out to become a "weak link" in managing these dense and increasing flows of information all over the planet. The next information revolution resolves this contradiction.

The Fifth Information Revolution.

High volumes of information being conveyed at high speed brought the need for machinery that would process it according to certain algorithms. In response to this need, the computer emerged. The essence of the fifth information revolution reduces to the automation of data processing and exchange. With the advent of computers, mobile intelligent "human-computer" systems, freely interconnected in networks of different types and levels, process a growing volume of information at an accelerating pace.

The fifth information revolution has given rise to an information society that is technologically based on the automation of information activity related to storing (accumulation), distributing (search), and algorithm-based data-processing (orders of linguistic signs and constituent elements of physical objects). People more and more specialize in producing new information. Exercising creative activities, achieving the personal potential for intellectual, social, cultural, spiritual, and moral development becomes man's most important task. By thinking and improving, working and creating, man increases volumes of information, establishing new orders in society, culture, economy, nature, life, and thinking.

As the information society develops, its networked nature becomes more apparent. A variety of different networks, operating concordantly in public life, structures the society in question. The network is a universal principle and the main mode of modern information activity. It is a flexible and open social structure that creates information (orders and varieties) of a particular type. The network rests on digital technology employed to store (accumulation), distribute (search), and algorithm-based processing of high-volume data.. The information society runs as a productive social community with a very high degree of mobility, adaptability, creativity, openness, internal dynamics of relations, forms, and contents.

1.3 Time Frames of Information Revolutions

Five information revolutions define human history from the creation of humankind to the present. Each previous revolution shapes the conditions for the next one. Together, they illustrate the purpose of human existence in the universe: the continuing evolution via a growing volume of information — the varieties and orders in the creation.

Information revolutions are the main stages of the historical development of the activity. Fueled by the first revolution, information began to be stored and accumulated out of the body — an animal turned into a human. The second revolution changes information processing mode: articulate speech based on signs — primal elements for information encoding. Articulate speech — external work with information in the processes of articulation — shapes thinking, i.e., an inner (psychic) nature of information activity. The unity of the two ensures the development of the man's practical object-oriented activity. The third information revolution launches the forthcoming of writing, culture, and the state structure; a civilization emerges. During the fourth one, there are drastic changes in the modes of information delivery and data-carriers movement. The contemporary information revolution logically completes the entire previous human history. Today, all information activity functions — storage, transmission, and processing – are performed out of the human body. Any activity can be considered informational in a broad sense of the term since it always aims at creating new orders of both linguistic signs and the constituent elements of the physical objects. Therefore, human activity is passing into a qualitatively new phase. The systematization of the information revolutions time frames provides a definite answer to what this new phase is and when a new era of humanity may begin.

Information revolutions	Defining events	Approximate historical time from the present (in years)
I	The first working tools	**2 500 000**
II	Articulate speech	**50 000**
III	Writing system	**7000**
IV	New communication and transportation technologies	**200**
V	The computer, computer networks, the Internet	**60 – 25**

Comparing the historical time frames of information revolutions, we find a remarkably consistent pattern: ***a timeline of each succeeding information revolution goes up by an order compared to the preceding one.***

This factual pattern can be defined as *the law of exponential growth of information activity.* With time flying faster, the speed of revolutionary changes and the time for the qualitative refashion of technologies and social relations grow down. The fifth information revolution is moving fast: its total time, from start to finish, is measured in decades. Its historical starting point was the invention of the first transistor-based computer in 1957, and it entered its active phase with the advent of the Internet in 1995.

The sixth information revolution is theoretically possible in the foreseeable future. According to the law of exponential growth of information activity, its duration should not exceed ten years, which is a flash on a historical scale. The sixth revolution will fall like a snap event that will change the world qualitatively.

This event is defined as the technological singularity. It refers to the time in history when technological progress will become so skyrocketing and complex that modern scientific language fails to describe it; it stays beyond our comprehension. Vernor Vinge believes this time may come around 2030. Raymond Kurzweil gives a different year — 2045.[5] Everyone agrees that technological singularity will be associated with artificial super-intelligence.

The technological singularity is predictable: the fifth information revolution should soon come to an end, and the historical process will predictably move to a shockingly new reality. It is hard to say what will happen next: technological singularity is indeterminate within the current thinking forms. But one thing is clear — it is going to be a different story of humanity. The historical growth of information activity typically leads to profound changes in human life.

The world is on the threshold of a new information revolution that will ensure storing, transmitting, processing and creating innovative data (new meanings) out of the human body. This upcoming future may make the very human existence in the universe unnecessary unless man matures. To survive and further participate in the universe's evolution, humanity needs simple, clear, reliable, and mass-scale technologies for managing its future. Education is one of those. To manage the future, fashion human personality, line of thinking, and human activity, a qualitatively new education system based on digital information technologies and the integration of natural and artificial intelligence becomes necessary.

[5] THE SINGULARITY IS NEAR: When Humans Transcend Biology By Ray Kurzweil, Viking Press. http://www.singularity.com/qanda.html.

Chapter 2. Education in the Age of the Fifth Information Revolution

2.1. Informatization of Basic Education

The fifth information revolution began in the 1950s of the last century and continues today. Digital information technologies have a significant impact on all aspects of the life and activities of man and society. In education, it runs primarily as a process of informatization.

In terms of both the coverage of educational organizations and expenditure, informatization is the largest and undoubtedly the most significant innovation in the education system in the second half of the 20th — early 21st centuries. It suggests providing education with the theory and practice of the latest information and computer technologies to achieve learning goals and manage the learning process.

The emergence of computers became a starting point of informatization. In the USSR, the design of the first electronic computers dates back to the early 1950s. Experimental work to study the basics of programming and pre-professional training in computer programming in high school began in September 1959.[6] The start of a new activity — programming — along with recognition of its importance for the economy led to the fact that in 1961, the Ministry of Education of the RSFSR approved the first official computer programming curriculum for schools with an in-depth study of mathematics. The Council of Ministers of the USSR " came up with the decree "On Measures for Further Improvement of Secondary Schools," providing the introduction of such electives as: "Fundamentals of Cybernetics,""Programming

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[6] Schwarzburd B. I. From the experience of working with students of the 9th grade who master laboratory programmers' qualification // Mathematics at school-1960. - N 5. - P. 9-16.

Languages,”” ECM Design,” etc. in 1966. The academic subject “Fundamentals of Computer Science and Engineering” became mandatory for study in all USSR schools from September 1, 1985. Informatization of schooling from the late 1950s to the late 1980s had some peculiarities. The learning occurred in the current absence of software and computers in schools, in other words, strictly in theory and as part of particular student courses with no opportunity to apply digital technologies and corresponding knowledge for organizing the learning process at large.

Computer classes appeared in Russian schools in the 1990s. The active period of informatization began. The school procurement with information technologies has been ongoing since then. Educational authorities, organizations, and actors of education are provided with hardware and software and have access to regional, national, international, and global networks. Electronic educational resources are developed and available on the Internet. Various databases are formed and integrated at the regional and state levels. A system for shaping ICT competencies among teachers and students is built up. Informatization enhances the presentation of teaching information that makes it more accessible and engaging for students and contributes to better knowledge acquisition. Information-and-learning environments are created, and multimedia programs open up ample opportunities for using computers in all subject domains, including humanitarian ones.

Since 2001, the computerization of education in Russia has been carried out on a program-based and goal-oriented basis. The Federal Targeted Program for the Development of a Unified Educational Information Environment was implemented. Thirty thousand secondary schools received full-fledged Internet-connected computer classes. The buildup of a single electronic library with digital arrays of study books began.

The project "Informatization of the Education System" was completed in 2005-2008. Its most important result was creating a school information environment as a holistic infrastructure integrated with the information environments of other schools, methodological support services for education, and information managementsystems.All Russian schools were connected to the Internet, and the student's workplace was determined by the 1:1 model (one student — one computer) by 2010.

Several projects for further informatization were completed in 2010-2018, namely, the introduction of electronic diaries and electronic document flow in schools, the buildup of electronic textbooks, portals, and websites for the education system. The following are examples of what was open and remains in operation: the basic education portal[7], the online collection of digital educational resources[8], the Federal Portal "Russian Education,"[9] the Federal Center of Informational Educational Resources[10], the "Single Window Access to Educational Resources,"[11] the Federal Repository "Unified Collection of Digital Educational Resources,"[12] the Moscow Media Library of Educational Resources[13], the Media Library of Methodological Materials for Teachers[14], etc. They contain digital collections on all subject categories with free access for all schools in the country. Networked teaching communities constitute a single information and education space: Pedsovet.org.[15], Open Class[16],

7 www.school.edu.ru/

8 www.school-collection.edu.ru/

9 http://www.edu.ru/

10 http://fcior.edu.ru/

11 http://window.edu.ru/

12 http://school-collection.edu.ru/

13 http://store.temocenter.ru/

14 https://infourok.ru/

15 http://pedsovet.org/

16 http://www.openclass.ru/

Network of Creative Teachers[17], etc., which allow education workers to communicate, address pedagogical issues, and raise their professional level.

The implementation of the provisions of The Federal Law "On Education in the Russian Federation" signaled a significant step towards the full informatization of education, decreeing the library stock of any educational establishment to be equipped with both print and electronic textbooks and teaching guides. E-versions became a prerequisite for publishing any textbooks and including them in the Federal List of Textbooks from January 1, 2015. An electronic copy must correspond to its paper version and complete the textbook with multimedia and interactive features.

Thus, over the decades that passed from the advent of personal computers and the first Internet connections in Russian schools, both the State and the business have done a lot for education informatization. Today, a single telecommunications infrastructure is launched based on the integration of computer tools, information, and communication technologies. It combines geographically allocated online educational resources, education management tools, methodological support, and tools for developing teachers' skills. Informatization contributes to meeting information needs, ensuring citizens' rights in the field of education, and improving the efficiency of public authorities and organizations through digital resources. The consistent implementation of informatization has ushered education into a new digital reality. The basic education content and its methodological support have been digitized. The content has become available to any learner anywhere and at any time to the extent needed. The cost of educational services has decreased, and their diversity has increased markedly. An open information-intensive learning environment has been built up. Actors of education have access to all digital educational

[17] http://www.it-n.ru/

resources and the possibility to choose. Multimedia and interactivity greatly facilitate the perception of the training material. The teacher training programs have been significantly updated. The computer literacy of education participants empowers their active online communication.

2.2. Boundaries of Informatization of Education

Being consistently implemented over the past decades, informatization has expanded learning opportunities but has not notably changed its content. The latter is essential to learning and generally defines its nature. If content does not change, then learning processes and outcomes remain unchanged. Despite computerization, the schooling continues running as a mostly reproductive process aiming to transmit objective knowledge and shape standard skills. The digitization of content has no much effect on content mastery.

From the beginning of informatization in the 1960s to the present, education is conducted in its traditional forms. In recent decades, the school has used digital data, multimedia, information, telecommunications networks, and other digital tools to transfer the learning material through communication channels and facilitate student-teacher interaction. But the content remains unchanged. An example is an electronic textbook. It is an electronic version of a traditional paper textbook with advanced features and convenient services. Apart from the text, it has multimedia material. It offers interactive blocks for knowledge testing and self-testing. It also allows for searching materials from encyclopedias, dictionaries, video files, copies of documents, changing font sizes, making notes and bookmarks, and adding learning material prepared by the teacher. However, in pedagogical terms, an electronic textbook is no different from a paper one because the purpose it is created for remains the same:transmitting ready-for-use knowledge and shaping skills and abilities.

E-learning tools, widely used in education for more than 30 years, do not have a notable impact on the quality of learning. This problem has been recognized for a long time. Back in the early 1980s, for example, there was a debate in the English-speaking world about whether the paper textbook was less effective than the newer media of the day. The results of studies[18] even then showed that using media did not enhance the learning process but even downgraded it in some cases. At the very beginning of the active phase of informatization of education, Richard Clarke figuratively and accurately assessed the impact of new technologies on education: "Media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition."[19]

Informatization of education, as it proceeds, sets its own boundaries beyond which its effectiveness is lost. At some point, it starts raising new socio-pedagogical problems.

Before the advent of the Internet, the school was the only social institution where a child could acquire the necessary systemic knowledge.The modern information society offers, for free or for a nominal fee, a large number of different educational programs that the learner can acquire out of school in an accessible mode. All the knowledge taught at school is easy to find on the Internet. Nonetheless, the school continues to deliver knowledge in the traditional vein. This calls into question the very need for traditional schooling.

With traditional learning on, the teacher's very status, both socioeconomic and academic, is steadily decreasing in the context of informatization. The teacher has always been a competent authority on scientific knowledge — a personified source of culture. The teacher's performance as a bearer of subject-based

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[18] Clarc Richard E. Reconsidering Research on Learning from Media // Review of Educational Research. Winter, 1983, Vol. 53, No. 4, pp. 445-459

[19] Ibid Pp. 445.

knowledge (as part of the curriculum) and teaching techniques are no longer of great social value in the information society. This knowledge is publicly available, and there may be cases whena student who is well prepared for a given topic knows more than a teacher.Reproducing available out of school knowledge in a classroom is inexpensive and has a low social value. The attitude of others toward a professional doing such work will no longer be as respectful as it was in the pre-digital era.

The everyday use of information and computing technology in school to achieve traditional goals, i.e., to assimilate and reproduce ready-for-use knowledge and work problems with ready answers, results in the brain-work fading. Saving time and effort, the learners plagiarize solutions to math problems, synopses, presentations, essays, research projects from the Internet. Such an approach weakens the already low impact of traditional learning on the learners' intellectual development. It degrades moral values: the students claim the borrowed work as their own, whereas the teachers, knowing this, often fail to prevent such behavior.

With traditional pedagogical relations, informatization negatively affects the socialization of the student and his state of health. The time of interpersonal student-teacher and student-student communication shrinks, their social engagement becomes quite rare. The level of student social awareness not only in class but also in life falls back, and the disconnection between all the participants in educational relations grows big.Informatization creates a contrast between a dynamic virtual reality full of vivid images, valuable information, and exciting events, in which modern children fashion themselves as thinking, acting, and communicating participants, and the world of school life, depressing with its monotony and lack of personal meanings in its content.

There is also a purely technical factor indicating the completion of informatization of education in its former forms. This process was carried out by States and businesses and was aimed at.

In 2010 — 2018, technologies were developing rapidly with the growing speed of information transmission, greater access to the Internet through an expanding range of gadgets. The ICT landscape at schools changed dramatically over those years. Smartphones became widespread. This has led to the student often having a more advanced digital device than the school can offer. Every student with a pocket computer has free and easy access to Internet resources, searching for or storing information, tackling learning challenges, communicating via social media. Further informatization of education without changing its content, forms, methods, goals, and values loses economic, social, and pedagogical significance. Computer literacy is formed among children starting from pre-school age, and students often outperform teachers in ICT-competencies. The entire educational content is already digitized and available on the Internet; supplemental education services database is built. Whatever new computers are available in class, learners will always have their state-of-the-art mobile gadgets. The tasks that were relevant in the late last century are fulfilled nowadays. Contemporary education is no longer responsive to the initial informatization policies. The grounds of those policies should be revised.

2.3. Digital Revolution in Education

Digital technology is continually improving and integrating into all spheres of economy and social life. Digital data have become a key factor in production, trade, communication, and management. The use of digital data significantly boosts productivity, quality of life and relationships, ensures rapid economic development and growth of wealth, and accelerates technological innovation processes. The fifth information revolution tremendously expands opportunities for storing, transmitting, and digital data processing.

Informatization of education has been going on for six decades now. Digital information technology is penetrating all types and modes of learning. It expands learning opportunities but has little impact on the pedagogical processes. Schooling is not evolving; its main content, tasks, modes, and nature of pedagogical relations remain mostly the same as they were a hundred years ago and in the old days. For the same six decades, digital technology has changed the very nature of economic activity. It has ensured the transition from the industrial to the modern post-industrial economy, also called the "Third Wave"(E.Toffler) and the Third Industrial Revolution (K. Schwab). "Around 1950, breakthroughs in information theory and digital computing began. These technologies formed the core of the Third Industrial Revolution… The possibility to store, process, and transmit information digitally has reformatted most industries. The labor and social relations of billions of people have changed radically."[20]Yet somehow paradoxically, education has so far remained on the sidelines of this revolutionary transformation in industrial technology and communications, despite its virtually complete informatization.

To understand the reason, one should consider the sequencing in which digital computing changes industrial technologies. Let us start with the concept of all four industrial revolutions built up by Klaus Schwab and Nicholas Davis to analyze industrial growth starting from the 18th century. According to this concept, technological innovation — discoveries, commercialization, implementation, and extensive use — is the dominating factor in the growth of wealth, well-being and a driving force of social progress. New technology leads to changes in the mode of manufacture, political systems, and social institutions. There were three industrial revolutions in the past 250 years. The first one began in

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[20] Schwab, Klaus. Technologies of the Fourth Industrial Revolution. - M. 2018. - P. 21

the textile industry in the mid-18th century, driven by the spinning and weaving mechanical aids mechanization. Then mechanization changed all other industries: machine tools, steel-casting works, steam engines, and railways. "Between 1870 and 1930, a new wave of technology propelled economic growth and further pressed the First Industrial Revolution's success. Radio, telephone, TV, home appliances, and electric lighting demonstrated the transformative power of electricity. The internal combustion engine gave a kick-start to cars and planes… The second industrial revolution signified the arrival of today's world: from sanitation to international air transportation."[21] The Third Industrial Revolution took place in the second half of the 20th century. Its driving force is digital information technology. The Fourth Industrial Revolution is now beginning. It aligns with the emergence of a radically new type of technology: the Internet of Things (IoT), quantum computing, biotechnology, etc. They are technologies of the digital economy. The main question is: how and by what logic does a rather short (by historical standards) transition from the industrial economy (the Second Industrial Revolution) to the post-industrial economy (the Third Industrial Revolution) and further to the digital economy (the Fourth Industrial Revolution) occur?

The logic is quite simple. The post-industrial economy emerges when digital technology penetrates all economic and social activities, markedly boosting their efficiency. However, industrial technologies remain almost the same as they were in the Industrial Age. Thus, modern industrial enterprises actively use information technology in working with suppliers, administration, and many other areas of their activities. But as before, people assemble finished products on the conveyor, control their quality, work in accounting and workshops. The nature of social and labor relations remains essentially the same as it was in the past centuries. This situation can

[21] Ibid

last up to a certain point. The efficient integration of new digital technologies into the industrial technologies created earlier leads to the expected result when digitally empowered industrial technologies start changing qualitatively. Advanced manufacturing technologies are emerging. The Fourth Industrial Revolution (4IR) begins, shooting off the digital economy. “The technologies of the 4IR can destroy even today’s digital systems and create completely new sources of values ... The 4IR will launch ecosystems for value creation that are impossible to imagine in terms of the Third Industrial Revolution.”[22] The Internet gives an example of the deep integration of digital and industrial technologies leading to a new production system. The first computers were built up and used as computing devices. Then, they were networked for faster and more convenient transmission of information than mail, radio, or telegraph. In 1995, the computer network became both an independent system and the top provider of information. Industry, trade, societal front, culture, and politics were beginning to embrace its opportunities actively. The Internet was turning into a system creating values, goods, and services.

At present, a new type of global production technology is advancing — the Internet of Things (IoT) — a network of material objects with built-in technologies for interacting with each other and the environment.

The historical development of education follows the same logic. Informatization of education has been carried out consistently since the 1960s. New digital technology was “overlapping” the old school teaching techniques, enhancing but not changing their nature. There was no substantial renewal of key training elements: the content and goals of teaching, organizational methods and modes, and pedagogical relations. In learning, as in other areas of socioeconomic activity, digital technology has reshapes the processes but has not changed their nature until a certain point

[22] Ibid Pp. 32-34.

— the advent of the 4IR. The long-term (more than half a century) impact of rapidly developing digital resources on traditional technologies, including educational, naturally leads to their fundamental and rapid change at a certain point in history.

The school is on the threshold of a digital revolution. It brings about a fundamental change of the very nature of teaching techniques, leading to a big breakthrough in goals, content, modes, methods, pedagogical culture, and the entire school workings. The digital transformation of schooling will become one of the crucial elements for the evolving digital economy. The digital revolution, technically based on decades-long successful informatization of education and urged by the necessity of shifting to a new-type economy, will end up with a digital school, as we predict, over a medium-term horizon.

A digital school will not come out by itself. Digital technology has developed only the necessary technological base. New schooling requires new pedagogical thinking. A scientific theory can answer the central question about the content of education.

Chapter 3. Historical and Pedagogical Context of Digital Education

3.1. Centralized Networks for Educational Content

Developing new approaches to the educational content takes lots of historical time with many scientists, entire scientific schools, and academic communities addressing this problem theoretically and practically. As the prerequisites for the digital economy were formed in the 20th and into the first decades of the 21st century, so a novel way of organizing the educational content for digital school was consistently shaped through innovative teaching processes over this phase of history.

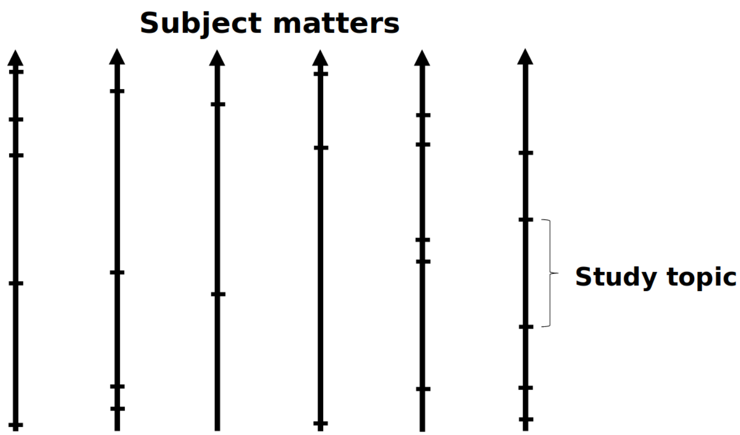
The first philosopher and educator who set the task of rearranging educational content radically and came up with a systematic scientific solution was John Dewey. Profound changes in the economy, politics, social life, ways of conveying information called for the "radical change in education suffices."[23] So radical that, as J. Dewey stated, "Now the change which is coming into our education is the shifting of the centre of gravity. It is a change, a revolution, not unlike that introduced by Copernicus when the astronomical center shifted from the earth to the sun."[24] For a better perception of Dewey's new approach, it is worth to compare it with the standard arrangement of educational content for traditional schooling.

The traditional approach to educational content tends to structure it by discrete subject matters, each as a succession of study topics. Didactic principles, both systematic and scientific, imply that the subject matter content is aligned with the content of a corresponding science, art, or type of activity. Systematic nature, consistency, and accessibility suggest the only possible arrangement

[23] J. Dewey. School and Society. M. 1925. P. 10

[24] Ibid P. 29

of subject-based content when the knowledge acquisition goes from the known to the unknown, from the simple to the complex, from a problem to its solution. The principle of using visual aids requires that both thinking and sensory perception are involved in assimilating the study topic content. The link between theory and practice suggests that theoretical knowledge should also be gained through practical activities, thus transforming knowledge into a skill. Classical didactics and its methods ensure the presentation and transmission of content within the boundaries of subject matters. Each subject matter has self-sufficient content and practices. Establishing communications between discrete subject matters is encouraged, but it is not mandatory or systematic. The schooling aims at delivering knowledge on discrete subject matters and shaping relevant skills and abilities. The quality control of educational outcomes falls within subject matters as well. The traditional organization of educational content can be shown as follows.



The model of the subject-based organization of educational content

J. Dewey formulates a different approach to the goals, content, and mastery of learning. He believes that the logical arrangement of educational content should rely on "not science, nor literature, nor history, nor geography, but the child's own social activities."”The ideal school curriculum should contain no artificial succession of studies...The progress is not about completing a succession of studies but, rather, about developing new attitudes toward, and interests in, experience." A major challenge of teaching is not so much to deliver knowledge, as "it comes down to the question of how the child develops his or her interests and abilities."[25]

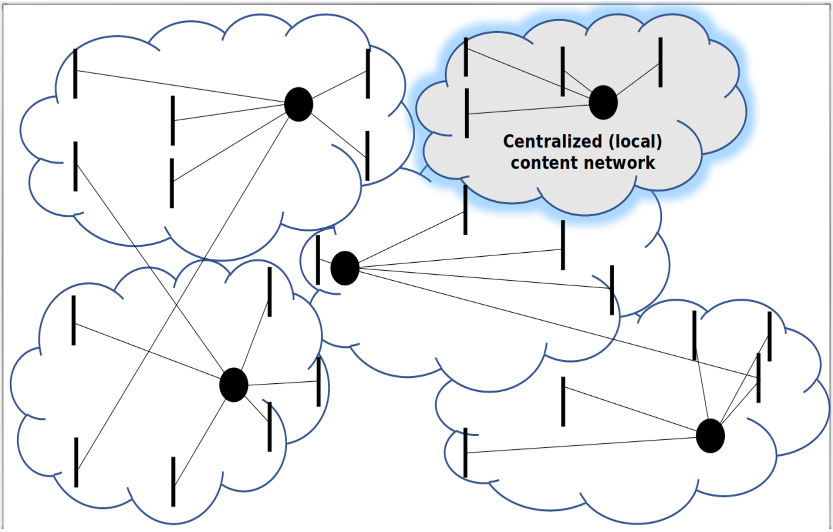
A comprehensive inter-subject organization of learning materials replaced the traditional subject-based approach to content for achieving these goal. The project-based learning substituted a reproductive method for the presentation, assimilation, and reproduction of ready-for-use objective knowledge. Subject matters lost their didactic self-sufficiency. The educational content was no longer divided into discrete subject matters, topics, and lessons. There were no permanent curricula with the successions of studies. Class times that complied with the aims and conditions for developing student cognitive interests could be freely changed.Standard teaching practices were pushed aside and helped implement the main pedagogical principle — developing each student's cognitive activity, shaping his intellectual abilities, social skills, and readying him for conscious, independent, and productive work.

This approach radically changes the education content configuration. The central organizational element was no longer a discrete topic of the subject matter presenting knowledge of science, art, or activity but a training complex. This complex comprehensively described an object, process, phenomenon of natural, social, and cultural reality. It also included knowledge items from various subject matters, skills, creative experiences, emotional, value-based

[25] Ibid

attitude towards the object under study, and training materials that learners were supposed to find and apply individually. The educational content was mastered through project activities.

In traditional schooling, its content organization falls within a linear principle (a sequence of topics within the boundaries of discrete subject matters). The comprehensive approach and project activities imply a different content configuration, which, in modern terms, could be described as web-based. Consider its organization on the model.



Model of educational content organized as centralized (local) networks

In this model,

• a circle indicates a subject-matter (theme) of the learning project;

• vertical segments — knowledge items from various subject matters, giving substance tothe project;

• lines connecting the circle and vertical segments — the contents of the learning activities of students who use multidisciplinary knowledge to complete a comprehensive training project;

• the "cloud" symbol outlines the boundaries of centralized (local) networks of educational content created by combining multidisciplinary knowledge.

As can be seen, educational content is divided into many training complexes, i.e., stand-alone local networks. In each, pieces of knowledge from different sciences (the peripheral elements of the network) center around a common learning objective (the center of the network). The students (with a teacher's assistance, if necessary) make meaningful connections between the center and peripheral elements while working on the learning project.

The comprehensive approach allows for building centralized (local) networks. Two factors account for centralization: integrating diverse pieces of knowledge centered around a common subject-matter (theme) and de facto abandoning the traditional subject-based (linear) organization of educational content. These networks are local because the integrality of educational content is achieved only within a given project.[26]Networked content

[26] The integration of educational content occurs within a particular project. J.Dewey illustrates it by the following example. Some learners receive the task of creating a working model of an ancient copper-smelting furnace, as far as possible in school settings. The introduction to the problem begins with studying the historical material. Where and when did people first start smelting copper? What was it used for? How did copper production affect the nature of social relations? After that, knowledge of geography and geology will follow. What ore is used for copper production? Where are copper deposits located? Then the learners should turn to the knowledge of chemistry. How does the metal smelting process work? What are the metals? How do you maintain the desired temperature? You can't do without knowledge of physics either. How do you create a furnace draft? For combining multidisciplinary knowledge items and making the model work, it has to be described in the language of mathematics. The solution of this practice-oriented task involves the integration of multidisciplinary knowledge items, sciences, technologies, creativity in applying different forms of reasoning and activities, and meaningful student-student and student-teacher cooperation for educational purposes.

— making for its semantic integrality — falls within a single training project and is not ensured didactically when moving from one project to another. It is assumed that the general context for different training complexes is the learner's life itself, the processes of his thinking and practical activities.

The comprehensive approach greatly enriches the content of education and opens up new learning-teaching opportunities:

• learners both acquire knowledge in various fields of science and create unconventional modes of activity, develop programs to implement those modes, integrate diverse scientific knowledge, put forward hypotheses, fashion their ideas and test them experimentally, etc.;

• students work with real-world objects or corresponding models;

• students regularly cooperate on addressing common tasks, which they define together with the teacher;

• the creative activity of students dominates all other types of their learning activities, which allows them, while doing research, to acquire learning material at a high conscious level;

• the learning process enhances student individual creative and critical thinking, readiness for cooperation, motivation for productive activity, perception of the value of knowledge; learners gain experience of self-actualization;

• students come to understand the practical value of objective knowledge and actively apply it for accomplishing non-trivial objectives in life, work, research, and others.

The comprehensive approach to the educational content was a philosophical and pedagogical response to the rapid and radical changes in transport, communication, and industrial technology that were in progress at Dewey's times. In the early 20th century, under the fourth information revolution, the world began to globalize, space and time shrinking. Large volumes of essential content-diverse information were compressed (integrated) so that man with individual experiences could easily place, move, restructure and use the data as the material, conditions, and tools for productive activity.

Dewey effectively makes the learner one of the actors involved in developing the content of learning. Becoming such an actor requires a strong motivation for learning. Students must be personally interested in searching for, selecting, integrating, applying, and consciously assimilating a vast body of knowledge. This calls for real-life problems that are understandable and personally meaningful for the learner. While pursuing "real-life" objectives, students work with multidisciplinary knowledge and gain creative experiences. Being consciously accepted by the learner, the problem determines the direction of thinking and practical activity. A personally meaningful goal guides and controls the learning process; it also provides a strong motivation for achieving it.

The comprehensive (network-based) approach for organizing educational content had, for the first time in history, appeared in the early 20th century. It aimed at shaping readiness for solo creative work with information (knowledge) and productive social activities. In the meantime, the volumes of information were growing, with data delivery and distribution becoming simpler. Also, the instrumental nature of information was developing, and the potential for its practical use was widening. Under such conditions, the traditional schooling, entirely aimed at transmitting objective knowledge and its simple reproduction in the learner's mind, was growing morally obsolete. There emerged a necessity in a new mode of organizing contentand readying learners for unsupervised and creative information handling: identifying key issues, searching for new knowledge, systematizing, analyzing, synthesizing information, making connections between various fields of expertise, and further applying them to real-life problems.

The comprehensive approach became the first progressive step towards the qualitative development of school educational content under the fourth information revolution. It did meet the demands of the time. However, its implementation seemed somewhat risky: it was necessary to abandon the traditional systematic subject-based organizational structure of teaching material partially or entirely. Lengthy pilot work was required to resolve doubts and assess the effectiveness of the integrated content arrangement in practice. In the United States, where the theory of comprehensive education appeared, it came to a few pilot schools, but that was not enough. A lengthy experiment in a mass school was needed. Soviet Russia conducted such an experiment in the 1920s. Already in the early 20th century, the world becomes global, and what happens on one side of the globe, in a short time, receives its continuation on the other.

After the Revolution of 1917, the new State needed a new education system. The State Commission on Education, headed by N. Krupskaya, A. Lunacharsky, and M. Pokrovsky, became the Soviet School Headquarters. Works on curriculum and methodical support for the new educational content spanned from about 1919 to around 1923. From the 1924/25 academic year, new curricula were introduced in grades 1 and 2. Primary school education was built on a comprehensive framework. The subject-based system was canceled. The learning process was structured around the three major areas: Nature and Man, Labor, Society. The educational content was organized according to the "method of life complexes."”To labor this definition," explains one of the new school's theorists, T. Rubinstein, "we should remember that each act of living labor, as opposed to the logic-based crushing into separate scientific fields, is always more or less and yet a many-sided composite: it is always the unity of diverse characteristics, which science with its logic-based thinking studies separately, but in life, they are always merged, complex ...".[27] The

[27] Labor School in the Light of History and Modernity/ed. by M. M. Rubinstein. L., 1925. P. 162.

real world, life, and activities in their various forms were building up for educational content. In a new school, “ the student should study the world and life, not arithmetic and physics.”[28] For this purpose, new programs offered comprehensive topics as Seasons, Potato Cultivation, Gardening, Agricultural Labor, etc. It was a big national experiment in teaching. It ran for almost seven years. In 1931, the Communist Party Central Committee Decree “On Primary and Secondary School” rejected comprehensive education; there was a comeback to the traditional school workings.

The experimental practices of 1924-1931 stood on the ideas of J. Dewey, whose works were widely known in Russia in the early 20th century. Soviet Russia implemented his governing ideas: about the relationship between learning and real-life work, the social orientation of education, the everyday use of project-based modes of teaching, the learning process based on accumulation of learners’ experiences, the integration of the knowledge items related to discrete subject matters, sciences, and arts within comprehensive study topics, etc.

The large-scale national experiment of the 1920s convincingly proved the social and pedagogical failure of the new approach to educational content organization. Making the content comprehensive led to de facto abandoning of the scientific platform (there was no need to study “arithmetic and physics”) and insufficient systematic knowledge about phenomena, objects, events. The new approach notably complicated the teacher’s work and opened the door to all sorts of subjective associations substituting the intra-subject objective and strict logical connections of scientific nature. One of the contemporaries evaluated the results of comprehensive training: “I have seen,” Blonsky P.P. stated, “ teachers who could link anything to everything lightheartedly. It is all chatter, not science… You can not occupy children with any association that may accidentally appear in your head about the phenomenon

[28] Blonsky P. P. Labor School. Moscow, 1919, Part 1. P. 46.

under study. I have also seen those who could mentally fly to South America while discussing a leg of the classroom desk… as well as a few unsuccessful attempts to unearth deep scientific connections with children: it is difficult."[29]

Suppose a teacher faces great problems in carrying out his professional activities. In that case, a student starts having difficulty learning, and a scientist who observes the process fails to comprehend the teaching logic. Therefore, obviously, something goes wrong. The comprehensive approach, the way it was implemented in the 1920s, failed to set up a new school. New problems came to replace the old ones. The traditional schooling detachment from life gave way to a lack of understanding of life-related scientific regularities; a lack of essential communications between subject matters brought about an incomplete and eclectic content scattered across discrete training complexes (local networks).

J. Dewey had a great influence on science and education in the 20th century. He was the first educator to identify the opportunities of a new era — the era of a global, open world of information, in which man can handle large amounts of diverse quality information and perform as a free, competent, and creative person. However, the endeavor to set up a new type of school took the easiest and unreliable turn — through the total negation of the traditional subject-based arrangement of educational content. In fact, comprehensiveness was defined as non-subject, which inevitably led to the destruction of the class-lesson system, sustainable modes of learning, and the entire traditional school's tenor. The experimental testing of comprehensive training across the world, on a large or smaller scale, did nowhere result in an outcome that would shift away from traditional subject-based learning. However, John Dewey's pedagogical influence has not lost its significance and is widely represented in contemporary teaching by "soft" modes of holistic education: training projects, cross-curricular assignments, interdisciplinary training research, etc.

[29] Blonsky P. P. New Programs of GUS (State Academic Council) and the Teacher. M. 1925. P. 24.

3.2. Decentralized Networks for Education Content

A quarter of a century later, at the onset of the fifth information revolution, demand for the new organizational structure of educational content started reviving in the USSR. In 1958, [30]the Law "On Strengthening the Linkage between School and Life and Further Development of the National Education System in the USSR" was adopted. From then on, education began to develop, and pedagogical science to study inter-subject communications. As in the case of comprehensive training in the early 20th century, the interest in interdisciplinary relationships also questioned educational content in the light of social life and human activities. In the 1950s-1960s, intersubjectivity was mainly considered in the context of strengthening the linkage between subject-based and vocational knowledge and readying students for work (P. Arthourov, S. Batyshev, M. Kondakov et al.). In the 1970s, the problematics expanded further, focusing on the challenges of establishing and developing content-based linkages between all school subject matters (I. Zverev, V. Maximova, M. Levina, N. Loshkareva et al.).

With solidarity in learning objectives, interdisciplinarity compared to comprehensiveness was a new step towards educational continuity and its deep integration with human life and activities. The principal drawback of the comprehensive approach, i.e., the de facto denial of the subject-based organizational structure of educational content, was overcome. The 1920s experiment proved that reproducing real-world objects and their relations in educational content, readying learners for practical

[30] A synergy of dates indicates a deep connection between the emergence of the computer, informatization of education, and the new approach to educational content: 1957 – the creation of the first computer on transistors with a high–level programming language, 1958 – the beginning of the development of inter-subject linkage in Soviet-era educational content, 1959 - the first computer science lessons in the USSR schools.

activities, fashioning their thinking could not happen by abandoning systematic scientific knowledge that school subject matters contained. Securing the subject-based school workings became a prerequisite for the integrality of education content.

Inter-subject communications do not exist by themselves; they are established between the content components of various subject matters. The teaching potential of those communications can be unlocked only by competent implementation of subject-based learning. Also, the scientific status of inter-subject communications is high. In the 1970s, there was an attempt to introduce a new principle into didactics: "...Inter-subject communications reflecting real-life connections in learning are an expression of the objective world regularities. Due to their philosophical and didactic meaning, they determine the content, techniques, and modes of education... Therefore, there is every reason to consider inter-subject communications as one of the principles of Soviet pedagogy (didactics)."[31] The approach, in which interdisciplinary relationships constitute the" principle of constructing a didactic system,"[32] sets their fundamental tone, defines them as the basis for organizing the content of education.

The unity of subject matter and intersubjectivity entails a radically new configuration of educational content. Students acquire systematic scientific knowledge within subject matters, build necessary skills and abilities, and master the languages of the corresponding sciences and arts. The content of traditional subject-based learning is fully secured. Besides, systematically building inter-subject communications envisages and shapes new

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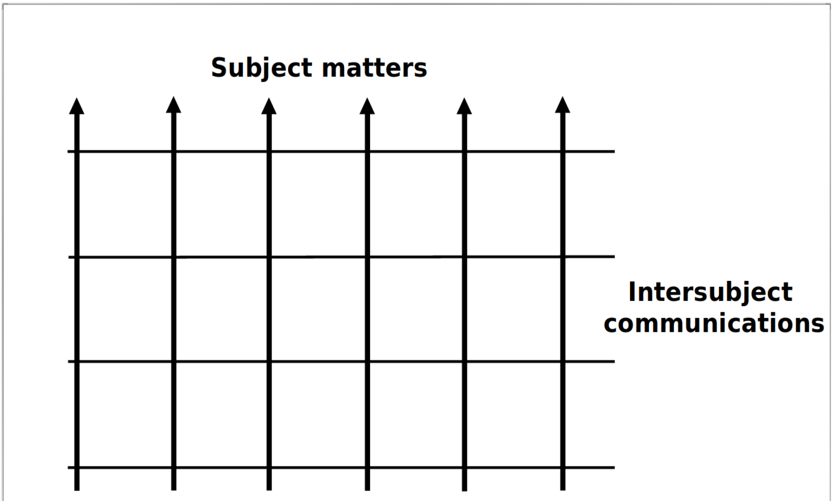
[31] Loshkareva N. The Place of Inter-subject Communications in the System of Principles of Soviet Didactics / / Inter-subject Communications in Teaching the Basics of Science in Secondary School. Moscow, 1973. Part 1. Pp. 36-37.

[32] Levina M.M. Inter-subject Communications as Didactic Techniques for Learners to Build Scientific Concepts and Awareness about Methods // Ibid. P. 60.

areas of cross-curricular content. It shows in addressing complex tasks, project activities, interpreting scientific concepts in broad sociocultural contexts, systematically applying the notions related to discrete subject matters to work on cross-curricular assignments, comprehending the other subject matter contents, and creating a holistic picture of the world. The unity of subject matter and interdisciplinarity enables the content of education to grow and markedly changes its structure. Let us consider the content structure.



Model of a decentralized (distributed) network of educational content

In this model, the vertical vectors show subject matters and their contents. The horizontal lines — systematically organized cross-curricular contents. One can clearly seethat the unity of subject matter and intersubjectivity shapes the coherent content of education on a network basis.

The pedagogy didn't employ the notion of "network" in the 1960s-1980s when inter-subject communications were actively developing. However, at that time, computer networks started being built and gradually centralized[33], culminating in the advent of the modern Internet. Under those circumstances, albeit not fully realized, there stemmed a real need for new approaches to the content of education that would correspond to actively developing networked social relations. Inter-subject communications opened up potential for shaping networked content.

The notion of a "network of educational content" defines its specific didactic arrangement aimed at integrating multidisciplinary knowledge. In centralized (local) networks, the integrator is a complex task. Inter-subject communications allow for creating networks of another type. They (networks) arrange the subject-based and cross-curricular lines of content on the system level. The line intersections form methodical "nodes" permitting to tackle subject-based learning challenges with maximum efficiency when knowledge is purposefully acquired and further applied in conditions different from those in which received, etc.

The unity of subject matter and intersubjectivity offers opportunities for setting up *decentralized (open or distributed)* networks of educational content. They overcome the disadvantage of local networks centered around the selected comprehensive topics and balance well with the subject-based organization of educational content. In decentralized networks, a single educational content is generated through a convergence of discrete subject matters. The networks are open, as a network structure allows for integrating the contents of diverse subject matters, modes, levels, and types of education. They do not have dominant centers and can connect

[33] In 1962, Joseph Licklider published the work "Galactic Network" on the computer network concept developed in detail for the first time. In 1969, the ARPANET network was created. It implemented the principles by which the Internet was built. In 1984, the NSFNET, with a proven set of open communication protocols, emerged. The connection was free, and by 1992 more than 7,500 small networks got already integrated into it, including 2,500 outside the USA.

a particular content element of one subject matter with the similar-meaning content elements of others. Inter-subject communications are specific information channels that are methodically structured and connect multidisciplinary content, not destroying the traditional subject-based content arrangement.

Inter-subject communications were developed and entrenched in the 1960s — 1980s. In the early 1990s, there was a notable decline in interest in interdisciplinary relationships. They were replaced by integrative forms less complicated to develop and introduce: integrated lesson, integrated course, integrated subject matter. The idea of intersubjectivity did not sway away from education and pedagogical science. It changed the way of implementation. The reason for this transformation appeared to be a contradiction between the theoretically ideal content arrangement based on the unity of subject matter and intersubjectivity and the impossibility of implementing the idea in practice by individual teachers manually processing teaching information.

Inter-subject communications are theoretically flawless, and, in their unity with the subject matter, they make for the integrality of educational content within the core curriculum. Although, making use of them requires the utmost effort from the teacher. The pursuit of both the cross-curricular approach and the integrality of content called for as many inter-subject communications as possible. The so-called "coordination grids" for all subject matters sprang up in the 1970s. They set out the possibilities to apply one subject-specific knowledge items to study other subject matters. At the time, the diversity and number of inter-subject communications were rapidly growing. Their classification was developed. They were divided into three groups: 1) content and information; 2) operation and activity; 3) organizational and methodical, then — into 14 classes. For example, content and information relationships were classified by 1) scope of scientific knowledge, 2) awareness of value orientations,

3) awareness of methods and forms of cognition. The latter was divided into types: philosophical, historical-scientific, gnostic, semiotic, logical.[34] A total of 44 types of inter-subject communications were identified. The total number of those types was nearing fifty and became difficult to calculate. Working with inter-subject communications as their number was growing began exceeding the realistic capabilities of the subject teacher. The demands placed upon the teacher grew by much. The teacher had to "relate the notions from discrete subject matters to each other for their further thingification, generalization, and colligation, also for shaping a system of notions of varying degrees of colligation, their subordination, and development, explanation of cause-and-effect relationships.., between theories of different sciences.., between the structural components of general scientific theories.., between theoretical knowledge and methods of cognition.., between the elements of axiological knowledge obtained by learners in the study of various subject matters; establish links between science and all other forms of public consciousness...".[35] The subject teacher had to master notions, theories, cognition methods, and teaching techniques for the other school subjects. For mastering personally and being able to shape student "ability to explain the processes and phenomena of a single science using notions of another science.., to give an element-by-element comprehensive characteristic of a complex interdisciplinary concept.., the ability, based on the theory of a single science, to explain the facts studied by an adjacent science..",[36] one needs professional training and high qualification in each of the fields of knowledge that are subjected to cross-curricular linkages. The evolution of

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[34] Zverev I. D., Maksimova V. N. Intersubject Communications in Modern School. Moscow, 1981. P. 43.

[35] Maksimova V. N. Intersubject Communications in Contemporary Schooling. Moscow, 1987. Pp. 153-155.

[36] Ibid

inter-subject communications placed an excessive demand on teachers and set out the tasks they could no longer fulfill. Having some knowledge of a relevant school subject is one thing. Mastering the knowledge, concepts, theories, and methods of other sciences and employing this tooling to address complex tasks the teachers confront is different.

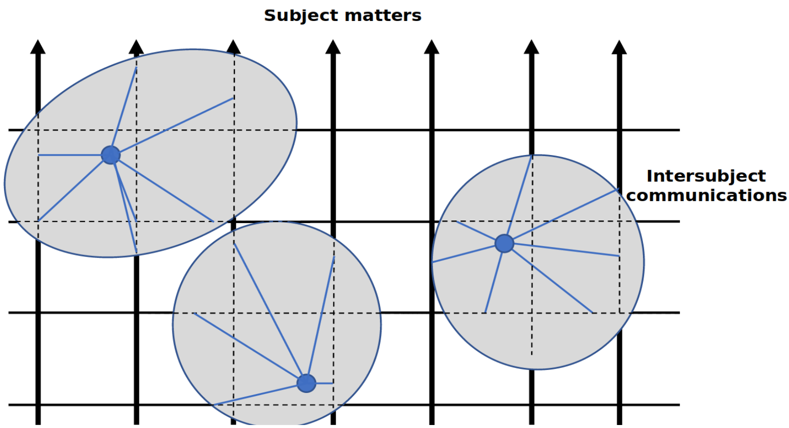
With interdisciplinary relationships growing, the teacher had to either ignore their infinite diversity and work within their subject matters or single out a few intersubject communications as integrated lessons and courses; the latter could quite well supplement their subject matter. Thus, the new modes of learning emerged.

Integrated courses were relatively compact organizational forms that included systemic knowledge as parts of diverse subject matters and reproduced nature-made objects, societal processes, forms of activity. Evolving interdisciplinary relationships were setting the stage for the courses to emerge. Such notions as a cross-curricular issue and a cross-curricular cognitive learning task became generally adopted by didactics in the 1970s. Thus, inter-subject communications acquired some didactic autonomy: a cross-curricular issue is identified, separated from the others, localized in the educational space and time, content-outlined, and requires a particular set of methods and knowledge items for comprehension. Cross-curricular issues began to structure inter-subject communications, organize them into a coherent cognitive complex (a particular set of multidisciplinary knowledge items for pursuing practice-oriented objectives),providing an understanding of certain objects, relationships, natural phenomena. The most important feature of integrated courses was their subject-based organization. They owed it their popularity. Integrated courses were compact learning modes made up of coordinated content fragments related to different subject matters. They did fit easily into the subject-based learning system, did not disrupt the teacher's general performance, suggesting neither excessive energy nor time.

While being attractive and relatively easy to design and practice, integrated lessons, courses, and subject matters did not ensure, in their own right, the structural unity of educational content as cross-curricular linkages did. In the 1990s, the network form of organizing content in the unity of subject matter and interdisciplinarity was leaving the practice of mass school education.

3.3. Two-Tier Network of Educational Content

During the fourth and fifth information revolutions, the search for and practical testing of new approaches to the organization of the content of education is active.All of them aim to make the content holistic, at least within the core curriculum, to ensure the transmission of knowledge and shape corresponding skills. They also involve enhancing every student's independent creative thinking and readiness for productive social and practical object-oriented activities.The historical development of education determines how to meet those challenges: integrating multidisciplinary knowledge in the form of centralized (local) and decentralized (distributed) networks. The centralized network includes comprehensive project-based training as well as integrated lessons, courses, and subject matters. The decentralized network is based on systemically organized inter-subject communications that, in cross-curricular contexts, connect, supplement, and reveal subject matter contents. Analysis of historical experience suggests that the network principle is decisive in organizing the content of education in a digital school. We call this structure *a two-tier network of educational content.*



Model of the two-tier network of educational content

The network has two tiers of didactically organized educational content. The first — basic — tier is made up of subject matters and systematically traced inter-subject communications. The decentralized (distributed) network of content is built upon the unity of subject matter and interdisciplinarity. It covers the entire content within the core curriculum. It also ensures the unity and interconnection of all the elements of educational content through integration (inter-subject communications) and differentiation (subject matters).

The second tier is built on top of the first one and consists of the centralized (local) educational networks. The model shows them as ovals. Such networks hold the content generated through developing and practicing the active modes of teaching: projects, cross-curricula tasks, training research, business games, case-studies, etc. They all share the following characteristics:

• the existence of a certain perceived problem that requires the learners to be self-reliant (in the model, these problems are shown as small dark circles inside the ovals);

• turning a problem into a task by formulating it as an activity goal;

• student choice of tooling (mainly knowledge and skills) from already ingrained subject-based and interdisciplinary content to tackle the task (in the model, the outsourced tooling is shown as rays going from the central "problem" to the subject-based and inter-subject lines of content).

The two-tier network offers a comprehensive approach to organizing content, research-backed by J. Dewey and engineered as a project method by W. Kilpatrick in the early 20th century. As part of the method, content acquires a humanistic developing character and aims at shaping student potential for productive solo activity. From over a hundred years' worth of experience in using active modes of learning, it can be said that the comprehensive approach to content is viable when training is subject-based, and the learners have the opportunity to learn systematic scientific knowledge and apply it to solve non-trivial theoretical and practical problems.

The two-tier network of the content in a digital school operates as a single educational system, consistently ensuring essential didactic functions. At its primary subject-based tier, *a reproduction-oriented activity* is practiced: the learners absorb knowledge and build skills. Cross-curricular content supports *an interpretive activityrelated* to applying knowledge under new conditions, a more profound understanding of the content under changing contexts, modeling objects, processes, and phenomena by different scientific means. Mastering these two types of activity allows the learner to rise to the level of *creative activity.* Owing to active learning modes, they fashions their creative thought, self-seeks for solutions to problems, shapes necessary basic (universal) competencies, creates new information.

As one can see, there is no secret in what educational content should be in a school of the digital society. Everything is known and has been battle-tested for a hundred years. That said, the history of developing innovative approaches to the content of education clearly indicates a major setback for achieving a new quality in teaching/learning and its outcomes. It is the lack of technological support, per se, for implementing new approaches to the content of education.

This problem unmistakably manifested itself in the 1980s and laid the basis for the forced denial of inter-subject communications. All the work on shaping and using the content of education was entrusted to the teacher, which led to a contradiction between their real capabilities and excessive volumes of additional educational information that they had to find, methodically process, and employ for tracing inter-subject communications on a systematic basis. The teacher is professionally trained and can work effectively within their subject matter, transmitting knowledge and shaping skills. The network approach imposes higher requirements: constantly working with interdisciplinary content, systematically practicing active learning modes, shaping creative experiences, and forming a value-based attitude toward the subject of study. In a paper-based learning environment with manual information processing, these requirements are almost impossible to meet. Thesituation is changing with pervasive computing in education. The development and application of digital technology makes the networked integrality for educational content feasible and shaped as the unity of subject matter, interdisciplinarity, and active learning modes.

The digital revolution in education stemmed from the two major lines of its development in the 20th century: the network organization of content and the informatization of education. Combining these two crucial and most ambitious innovations in the paradigm of new pedagogical thinking opens up the possibility of setting up a modern type of schooling — a digital school.

Part II. Theoretical Basics of Digital Education

Chapter 4. Integrality of the Content of Education

4.1. Disciplinary Fragmentation Issue in Educational Content

There is no single content in the public education system. There is no linkage between subject matters, each working autonomously. We can only speak with certainty about a discrete subject matter integrity, whose content is organized by didactics and its teaching techniques. Each subject matter pursues its learning objectives, mainly reduced to transmitting knowledge and building skills. The questions of how the student's mind combines the items of interdisciplinary knowledge remain in complete disregard. In what way do different-type skills contribute to enhancing student functional capability? Neither classical didactics nor teaching techniques have ever raised these questions. Humanistic pedagogy declares the goal of shaping a personality, but the schooling does not progress it. The content of education, entirely focused on separate sciences, for the most part, is alienated from the content of real life of both the student and the teacher.

The content fragmented into separate subject domains became a pedagogical issue as early as the 1860s. "When deciding on the subjects to teach," K. D. Ushinsky asserted, "the schooling should pay attention not to sciences as discrete subject matters but the student's soul in its integrity and organic, gradual, and comprehensive development." He emphasized that teaching, "where one science follows another, colliding nowhere, even though it is very coherent in the program, produces chaos in the student's head, or even worse: those dead ideas lie in the head, as in a cemetery, knowing nothing about each other."[37] The mid-19th century marked the advent of the fourth information revolution. At the time, the economy, transport, and communication technologies were developing rapidly. The volume of information available was accelerating, and the spatial and temporal constraints in relations between people, social and economic actors were being eliminated. To man, the world was becoming large, complex, and holistic, calling for comprehension and action. Alongside this, the schooling continued transmitting knowledge understandable and applicable only within discrete subject matters, which were poorly related, if not at all, to each other and man's real life in a large and complex world.

As the economy was developing, particularly during the fifth information revolution, the subject-related fragmentation of educational content became a pressing issue. The problem took on an economic dimension in the second half of the 20th century. A crucial resource in the post-industrial economy was human capital — human readiness for productive activity. Integrating through activities, diverse knowledge related to various sciences and different skills became instrumental for achieving the goals of activities. The ability to manage knowledge and skills related to a wide range of sciences, arts, and other forms of consciousness gained in paramount importance. In the pre-digital era, being a well-rounded person was sufficient for man. It involved ideas about different cultural spheres and systemic knowledge in a separate science and practical activity that could turn into life work.However, in the early 21st century, professions are rapidly updating, and a person can change the type of professional activity several times during a lifetime. Clearly, this tendency will only be increasing. The assimilation of ready-for-use subject knowledge, which is related neither to other sciences nor modes of thinking nor methods of activity on

[37] Ushinsky K. D. Coll. Ed. Vol. 3. M.-L., 1948. P. 178; Vol. 10. M.-L., 1950. P. 435.

a systemic level, vastly reduces opportunities for a man to be an actor in the post-industrial and digital economy; both economies emphasize the productive work with large different-quality databases. Expanding globalization, a cross-cultural dialogue, and a convergence of different forms of consciousness create necessary prerequisites for understanding the world at large, anticipating the consequences and effects of activities, cooperating across borders, and acting with due regard to a large number of scientific, life, ethical, social, cultural, economic, and other values.

Learning is changing its priorities in response to the needs of the new economy. The competency-based approach is becoming the primary objective to pursue. Competencies make up human capital, the first string of the post-industrial and digital economy. Stand-alone curriculum techniques fail to build competency. It shows ability to apply knowledge in the situation much different from the one in which it was acquired. By mastering a subject matter, the learner can acquire systematic scientific knowledge. For building competency, the student must systematically apply this knowledge under new circumstances: in practice, in project activities, identifying and solving complex problems, modeling natural objects, studying other subject matters, etc.Knowing separate sciences per se does not shape competencies, and an incompetent person accessing modern digital technology can pose a danger to nature, other people, and themselves.

New state requirements for educational outcomes establish the need to coordinate the content, modes, techniques, and methods of learning.[38] The core curriculum should work as a single pedagogical system aiming to achieve overall educational outcomes. And yet, the educational content of schooling is still divided into discrete subject matters; their communications are not systematized.

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[38] Educational standards set requirements for individual results and meta-subject outcomes for each level of education. In Russia, their implementation began in 2009. Before, there were federal components of state educational standards (mandatory minimal content) for discrete subject matters.

A digital school aims to eliminate content fragmentation. It is feasible with networked content supported by modern digital technology under the already implemented informatization of education. However, the practical solution requires more specific knowledge of the didactic grounds for developing integrated content within, at least, the core curriculum. There is a need to find a method that will ensure integral learning. It has to be explicit and understandable due to its fundamental nature and technologically realistic for teaching practices.

4.2. Qualitative and Quantitative Approaches to Educational Content

The content of education, in its traditional sense, consists of knowledge, skills, and abilities. It also defines the learning objectives, which imply transmitting systematic scientific knowledge and building corresponding skills and abilities. Until the 1960s, when the fifth information revolution and informatization of education began, this approach did not arouse any doubt. "The content of education ... refers to the system of knowledge, skills, and abilities that learners must come to master in the process of training."[39]

It is easy to see that all three content components are essentially reduced to one point, namely, knowledge. An ability implies a human capability of using knowledge, and a skill is an ability driven to automatism with no mind control involved. The defining component of content is knowledge manifested in two forms: as a mental effort (knowledge per se, theoretical knowledge) and practical action (ability, skill).

There is every reason to define educational content through the category of knowledge. Rational, scholarly knowledge underlies modern civilization. "Knowledge is power" (F. Bacon), and a possibility to receive, assimilate, and apply knowledge shapes

[39] Danilov M. A., Yesipov B. P. Didactics. Moscow, 1957. - P. 45.

human intellect and man's readiness for practical object-related activity. Knowledge-based thinking and practices have molded man and humanity throughout history into what they are today. Through an inter-generational dialogue, knowledge transmission has been, still is, and will remain one of the most important learning objectives.

Alongside this, educational content defined only through the category of knowledge has methodological peculiarities and limitations. Knowledge is domain-specific. It implies specific knowledge of something conveyed by science, art, philosophy, or another form of social consciousness. This certainty inherently confers quality on education content. Objectively, both didactics and subject-based teaching techniques operate with educational content components within one or another curriculum. There is no large-scale knowledge in teaching practices. There is domain-specific knowledge of mathematics, physics, history, and other subjects.

This is what we call a ***qualitative*** approach to educational content. It defines content through knowledge that always relates to a particular type of cultural activity (science, art, etc.). The knowledge is acquired by performing this activity and presented through the relevant specific curriculum in learning. The qualitative approach for defining educational content has existed since the very first schools emerged. It is understandable, practical, and convenient. Nothing else is required as long as learning is carried out strictly within a specific curriculum and aims to transfer knowledge and build skills.

The 1960s-1980s experience of practicing inter-subject communications called into question the adequacy of the qualitative approach for the first time. Domain-specific knowledge and skills were no longer sufficient to describe the content of education fully, including broad interdisciplinary content. In 2009, the federal state educational standards for Russia set requirements for individual results and meta-disciplinary outcomes, achieving which required requires pedagogical management of the core curriculum's entire content. However, this task was hardly feasible to tackle by employing the qualitative approach when learning began splitting into separate processes, each bound to a given subject matter. Since the integrality of educational content was virtually absent, it was only possible to declare common state standards for meta-disciplinary learning outcomes and individual results. Only the goals of subject-based learning were achievable. There was no place for the individual or possibility for personal growth in education, which mechanically combined content-diverse areas.

A different approach to the content of education began taking shape in the mid-1970s. M. Skatkin, I. Lerner, V. Krajevsky defined it as a unity of four mandatory components: "1) a system of knowledge about nature, society, thinking, technology, and forms of activity... 2) a system of common intellectual and practical skills and abilities which are instrumental in various activities... 3) creative experiences accumulated by mankind throughout the evolution of social and practical activities... 4) an experience of emotional-volitional attitudes toward the world, to one another, and, when combined with knowledge and skills, being a prerequisite for shaping personal beliefs, ideals, and a value system".[40] The four-component structure of the content (knowledge — skills — creative activity — emotional-volitional attitude) supplemented the traditional two-component architecture (knowledge-skills) and markedly expanded the boundaries of educational content. For the first time, a personality-related component that included creative experiences and their outcomes, values, beliefs, ideals, emotional-volitional attitudes toward the world, other people, and real-world objects appeared to have become part of the content.

Learning goals do not grow inside the educational content. They trace their origin to the nature of socioeconomic and technological development in a given phase of history. The qualitative

[40] High School Didactics. Some Questions of Modern Didactics. Edited by M. Skatkin. Moscow, 1982. 2nd edition - Pp. 102, 103.

approach to educational content was fueled by the emergence and development of modern science in the 17th-20th centuries and the industrial economy of the mid-18th-20th centuries. In the mid-20th century, the post-industrial economy and information society were flourishing, and digital information technology was emerging and rapidly evolving. Information became a basic concept and core driver of socioeconomic development. The readiness to productive information handling via a wide range of technology (digital, intellectual, industrial, social, etc.) became a key competency and a new goal of education.

The approach for defining the educational content through the category of information became a ***quantitative one***. With that, the notion of "quantity" retains a well-known philosophical meaning. "Quantity," as Hegel defines it, " is the determinateness that has become indifferent to Being and is external to itself ."[41] Regarding all specific types of educational content, information is the "external,""indifferent to them determinateness."Precisely because of that quality, information, taken as the basis of educational content, gives coherence to all of its quality-diverse elements. It highlights those properties and relations that unite, compare, and integrate all the pieces into a single educational content. Assigning a status of the modern didactics core category to information is empirically justified: learners and teachers work with information, the learning process is composed of its diverse flows, and rational knowledge is just one of the types of information.

Information, as a fundamental didactic notion, opens up the opportunity for integrating pedagogy and informatics. The lack of tools for quantitative analysis of content has so far prevented the digital information technology potential from being used in the live pedagogical processes. Decades of informatization have not had a significant impact on the content of education, its

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[41] Hegel G. Encyclopedia of Philosophical Sciences. Vol. 1. Science of Logic. Moscow, 1975. - P. 216.

modes, methods, and relationships.While going digital, education changes only on the surface; the quality of its processes and outcomes remains the same. The reason is clear: pedagogy traditionally works with the content of education only in its qualitative dimension, which is of no importance for computer science. Using information technology for the development of teaching/learning processes requires that educational issues shall be formulated, among other things, in the language understandable to informatics specialists.

Knowledge is always the knowledge of something, i.e., it invariably has a meaning, which conveys quality information about an object.But the science of methods and processes for computer-based information processing is fundamentally immune to meanings.The split between information and meaning, the separation of quantitative and qualitative aspects of information, occurred as early as 1949 when Claude Shannon and Warren Weaver published the book "Mathematical Theory of Communication." For the first time, their work defined the conceptual basis of information. "The word "information," in this theory, is used in a special sense that must not be confused with its ordinary usage. Particularly, "information" must not be confused with "meaning."[42] Shannon and Weaver were interested in creating machines for storing, processing, and transmitting information. "The fundamental problem confronting communication is 'to reproduce at a given point in an exact or approximate way a message selected at another point.' These messages often have meaning… The semantic aspects of communication (related to the message loaded with meaning) are irrelevant to the engineering aspects".[43] Meaning is always contensive. It conveys the qualitative determinacy of Being. Digital technology stands upon

[42] Claude Shannon and Warren Weaver, The Mathematical Theory of Communication (Urbana: University of Illinois Press, 1963, 8).

[43] Ibid., 31.

purely quantitative relations based on numerical orders that can reproduce any qualitative determinateness.[44]

The quantitative approach to educational content has a downside: the lost quality of learning. How can it be recovered by taking information as the basis?

Information is the order of symbols and/or physical elements. In its most general form, the entire education content can be perceived as an open set of signs. They are organized in specific orders didactically and methodically. The sequences of signs constitute teaching texts in various formats: lesson topics, textbooks, curricula, homework, questions, and answers to exchange between the subjects of education, and much more. The content of education is composed of written texts and oral messages. It contains only texts (messages) and the educational subjects who assimilate and compose these texts (messages). Each text, or a sequence of signs, already has a meaning.

Signs shall be drawn up in sequences by certain rules. These rules exist within a particular sign system as the grammar of the corresponding language. The texts in the content of education are not chaotic. They are rigidly organized within the confines of a particular language (a sign system). Indeed, the learner does not assimilate the content as such, but the curriculum-based teaching texts in the languages of mathematics, physics, biology, etc. Shaping the ability to speak and think in the languages of these subject matters (sciences) is also an important pedagogical objective. Within the entire content of education, subject-related academic languages build up subject domains with the corresponding teaching texts to find, assimilate and apply.

[44] Computer science rules out any quality information and operates with a digit and a bit. As per the information theory, all information about any computable problem can be presented in the positional number system of base 2, i.e., using only two digits - 0 and 1.

Thus, the information-based quantitative approach allows for creating a coherent picture of education. The educational content is single by default since it consists of simple formal units — signs. Signs are arranged in sequences — teaching texts. The “grammars of languages” involved in the learning process define the rules for arranging signs.The applicability boundaries of certain languages establish specific content areas, which are known as academic subjects.The quantitative approach allows for conceiving and modeling the inherent integrality of educational content consisting of sign sequences (texts) and sign systems (languages). This approach also reveals a method for achieving the content’s integrality, which is understandable to both educators and IT professionals. This method rests on a reliable fact: all existing languages are mutually translatable. Therefore, translating (coding) educational information from one subject-specific academic language to another ensures the integrality of the content.

The process of translating (encoding) educational information must be modeled. But first, let us dwell upon languages (sign systems) that are actually involved in education.

4.3. Languages (Sign Systems) of Learning

Education exploits the notion of “language” in its ordinary and purely methodical meaning: it is both a native and a foreign language that must be mastered through learning. Such an attitude to languages stems from the traditional organization of learning. For language (a sign system) to become a meaningful concept of pedagogical thinking, it must be treated as an object of learning activity. However, in subject-based learning, the teacher invariably deals with the language (sign system) that corresponds to their subject matter. The teacher rarely switches to other subject-specific languages. It is sufficient to master a national language and an academic language of the science they teach for transmitting knowledge and building skills. These two languages shape an integral, self-sufficient (in terms of pursuing subject-based learning), relatively closed semiotic space of the subject matter. The teacher finds their subject matter ready for use and organized by a curriculum, textbook, methodical, and other teaching materials. They work within this space under pedagogical, didactical, and methodical rules.

This situation persists unless the need for coherent educational content emerges to achieve individual results and meta-subject outcomes and build basic competencies.The teacher faces the need to apply linguistic means of other academic subjects alongside the forms of thought derived from them (knowledge, notions, methods, etc.) while teaching their subject matter. In light of this, the attitude toward language changes markedly; it becomes the object of pedagogical reflection.

The need to achieve coherent educational content through interdisciplinarity, with the learning process organized not only "vertically" (subject matters) but also "horizontally" (interdisciplinary areas), allows actors in education to switch between different subject-specific languages seamlessly. In the ongoing interdisciplinary transitions, language becomes instrumental, becoming a means of addressing key pedagogical problems. For example, to have a solid and conscious grasp of a particular notion in biology, the teacher can build up an interdisciplinary relationship with chemistry. In this case, the language of chemistry becomes subject-specific (the biology teacher employs its method of thinking) and instrumental (the language tools of chemistry is used for a better understanding of the selected notion in biology).

The quantitative approach to content, which is a prerequisite for achieving its integrality, actualizes in pedagogy the notion of language in its general theoretical meaning, namely, as a sign system.Education functions on the basis of a given national language that forms its common communicative space. Many other languages (sign systems) are also present and methodically organized in this space. The principal subject-specific academic languages (for knowledge transmitting and skill building) are the languages of subject matters and corresponding sciences, arts, and activities. But they are not the only ones involved in learning. Learning is rich in languages (sign systems) of different categories and types.

Categories of Sign Systems in Learning	Types of Sign Systems in Learning
National Languages	Languages — Russian, Tatar, English, etc.
Languages of Science	Languages of mathematics, physics, biology, computer science, historiography, literary studies, etc.
Languages of art	Languages of painting, fiction, dance, etc.
Languages of Activities	Language of physical culture, sports, learning, etc.
Artificial Languages	Computer programming languages. Systems of reference signals created by teachers to facilitate a better understanding of learning material, etc.
Languages of Professional Communities	Languages of teachers, methodology workers, and education administrators
Languages of Social Age Groups	The language of primary school children, the language of teenagers, the young, and adults.
Individual Language Profiles	Personal parlance (a way of encoding and decoding information) that is peculiar to each participant in educational relationships

The national language provides a permanent and universal communication between the actors in pedagogical relations and builds the metalanguage basis for all other languages. All school subjects are taught through the native language, an intermediary language, a metalanguage that describes the entire heterogeneous semantic space of education.

The most influential group of languages for achieving learning goals are science and art: physics, mathematics, biology, history, literature, computer science, etc. These languages are created and evolve in the course of historical development. They underpin the relevant forms of social consciousness and focus on the cognition of nature and society. Information created and historically accumulated in scientific and artistic activities, stored in socially significant texts, constitutes the core educational content. The goal of subject-based learning is not only to acquire specific knowledge but (more importantly) also to master (within the curriculum) the language (way of thinking) of the science or art through which this knowledge was acquired.

With the extensive use of information technology, artificial languages gain in paramount importance. They are created to tackle practical problems: strengthening thinking capacity in cognition, software systems for automatic information processing, creating artistic images, etc. In learning activities driven by artificial languages, the language itself becomes an immediate object for actors of education: they can apply it, fashion it in some way, and even create a new sign system for their own purposes.

The phenomenon of individualization of language activity is of particular importance for education. Thanks to it, learning can occur even in environments with no objective systemic knowledge. Still, direct teacher-student (adult — child) communication ensures the evolution of thinking and the assimilation and creation of new information. The individualization of language activity occurs as a man grows up, socializes, and matures using objectively existing languages in real life. Over a lifetime, everyone builds up their vocabulary and elaborates, through various activities, their individual rules for sign operating. Man uniquely encodes

— decodes objective information in line with his personalized language system. Two people perceive and process the same information differently even if they have previously agreed on the content of the signs (for example, they have clearly defined the meaning of the notions they are going to use). Grammar — sign-operating rules — will always possess the person-specific distinctiveness when applied by a specific person. The vocabulary used by a person also has a unique profile. In this sense, everybody is a carrier of their individualized system of information encoding/decoding. Precisely because of the notable differences in individual language profiles, communication between people speaking the same native language can be engaging and productive. This kind of communication creates and processes new information.

The educational space involves many languages of different types, kinds, organizational levels, and sub-levels. In fact, the learning process is an elaborate, multi-hyphenate speech activity of many actors. In the information society with cultural globalization and ongoing scientific and technological revolution, the number and diversity of sign systems in education is now and will undoubtedly keep growing with the growing volumes of information, multiplying methods, modes, and technology for data processing.

4.4. Didactic Principles of Coherent Education

The integrality of educational content arrives via a two-tier network. For the time being, a very general and formal one, the idea of a two-tier network organizational structure is being gradually defined by analyzing key innovations in the educational evolution in the 20th century. The practical organization of digital education involves not only an understanding of the structure of the two-tier network of content but also knowing its didactic principles — the core requirements for coherent content, processes, and modes of digital learning.

The two-tier network of educational content stands upon three didactic principles: 1) *systematic and consistent training*, 2) *interdisciplinarity*, 3) *comprehensiveness.*

The Principle of Systematicity and Consistency. The primary, pivotal components of the two-tier network are subject matters. Within them, content is coherent. It features the unity of presentation, comprehension, and activity. Subject-based education focuses on transferring systemic knowledge, mainly scientific, and building skills. Within-subject matter, content is organized primarily by the principle of systematicity and consistency. Accordingly, "knowledge is communicated in a strictly systematic order with each subsequent scientific assumption stemming out of a previous one, and the previous one finding its further amplification in the subsequent one; when the initial premises, facts, and definitions of science lie at the core of all further acquisitions of students in this science."[45] This principle helps to elaborate curricula for academic subjects. It sees heavy use as one of the critical rules of learning: not to proceed with studying the subsequent unless the previous is assimilated.

The Principle of Interdisciplinarity. It defines the way of expanding the educational content by supplementing the subject-based with cross-curricula content.Inter-subject communications are set up between similar-meaning notions from different subject matters. It opens up possibilities to assimilate knowledge at a higher level of consciousness and durability, heightens interest in learning, and helps organize the learning process in the activity-oriented paradigm: using subject-matter expertise as a cognitive tool to master another subject. Inter-subject communications build up a specific content area. If the subject-based content comprises mainly knowledge and skills, initial creative experiences serve as a key component of interdisciplinary content. The student learns to apply knowledge in new conditions,

[45] Danilov M. A., Yesipov B. P. Didactics. Moscow, 1957. - P. 178.

transfer concepts and corresponding mental actions from one subject domain to another, and identify and address cross-curricular issues.The student learning activities carried out through various subject matters generate interdisciplinary educational contents. They supplement and expand the subject-based content. The unity of subject matter and interdisciplinarity takes the shape of a decentralized network, making for coherent educational content within the core curriculum.

The Principle of Comprehensiveness. It implies a real object-based activity. This activity integrates knowledge and skills, concepts and relationships, which are usually separated between academic subjects, into a certain complex underpinned by the commonality of the problematics. In the past, the principle of comprehensive training was ranked as an alternative to the subject-based learning mode. In the current context, the subject-based and comprehensive approaches supplement each other and relate to the different levels of content arrangement. Subject matters interpret the content of sciences and arts in simple terms comprehensible to students. Training complexes recreate objects, processes and phenomena of nature, societal and cultural events by employing multidisciplinary contents and inter-subject communications. Implementing the principle of comprehensiveness takes the form of a centralized (local) educational network. A great many networks of this kind constitute the second tier of the content network organization.

Any learning activity within a training complex (local network) becomes productive. Through training complexes, integrating knowledge from various subject matters and communications between them, students recreate objects of the natural and/or virtual (conceivable) worlds and simulate their origin and development processes. In this way, the content of education embraces a new component — a full-fledged creative experience. An information object is created (recreated) in the process of free, sensible, and reasoned activity. This process shapes a personal attitude toward the information object and its real-world prototype. The actor of education creates a piece of work by manifesting their will and reason and treats their creative work result as a personally significant value. Through the subject-based activity, which is carried out in the local network didactically and methodically, digital education adopts yet another component of the content – the emotional, value-based attitude toward the piece of knowledge being mastered.

Three didactic principles define the overall structure of the learning process in a two-tier network. It ensures the completeness of presentation and assimilation of the educational content in the unity of all four components: knowledge, skills, creative experiences, and an emotional, value-based attitude toward the material being studied. Each principle sets out overall requirements for learning outcomes and organizational forms:

• within-subject matter, systemic knowledge is acquired, and simple skills are developed (the skill to work problems with ready answers);

• the system of inter-subject communications shapes sophisticated skills (the ability to formulate and address cross-curricular practice-oriented tasks), elements of competency-based thinking (the ability to apply knowledge and skills under new conditions), and the initial experience of creative activity (the ability to use the knowledge gained and skills built to perform a solo intellectual activity);

• coherent interdisciplinary content, organized in a centralized (local) network, fashions creative experiences (recreating a natural object, process, phenomenon) and an emotional, value-based attitude toward the object under study.

The three principles underpinning the two-tier educational network define the didactic basis for the coherent content of education to be assimilated through productive, creative, and personally significant activities. Those principles have an inner unity. In its own way, each principle expresses some essential (core) action that predetermines the very possibility of conscious information handling.

All three didactic principles stand on the idea of moving from knowledge to knowledge. They embody this idea in different ways:

• from one domain-specific knowledge to the other to assimilate both;

• from the mastery of one subject matter to the mastery of another one for a keen insight into both, applying the knowledge gained in a new environment;

• from mastering many subject matters to the essence of their unity embodied in a real-world object, which different sciences study by their own unique means, aiming to build the ability to work with this object.

In educational content, knowledge represents itself as a teaching text or a sequence of signs in a particular language. Accordingly, moving from knowledge to knowledge acts out as a move from one sequence of signs to another, from one language to another. Moving from one language area to another is, at the core, a translation.

Translation can thus be seen as a pivotal method for achieving the integrality of the educational content. The notion of translation is not only didactic. Creating and developing a network of educational content requires the integration of pedagogical and digital information technology. It is possible only if specialists in pedagogy and computer science understand each other. In computer science, translation is the encoding of information with the target language. It is feasible technically. In the most general sense, translation conveys a verbal message or written text employing a different language.In information theory, coding is seen as converting data from one form convenient for direct use to another, optimal for transmitting, storing, and processing, thus becoming a new form for direct use. Didactics and teaching techniques in the context of networked content face nearly the same challenge: to transform the already acquired subject knowledge (certain information) so that it can be introduced into the context of another subject matter (another learning mode) and applied to pursue developmental learning objectives.

The notion of translation brings together pedagogy and computer science and opens up the potential for integrating pedagogical and digital technologies to enhance student thinking activity.

Chapter 5. Development of Thinking in Digital Education

5.1. General Notion of Thinking

The question about thinking is somewhat tricky because the object of cognition (thought, thinking) and method of cognition (thinking) coincide. Despite this, knowledge (awareness) of thinking exists and is feasible to gain since the method of cognition, which is an activity, differs from the mere act of thinking and changes over historical time.With the activity developing, more and more possibilities for understanding thinking open up.

In a generic sense, thinking can be defined as information handling. It is the ability to receive, store, and process it according to specific rules, including transmitting and creating new information in different languages as sequences of symbols and material elements (according to different sign/element operating rules). Living organisms can also receive, store, process, and transmit information. One can talk about animal languages as the diverse ways wild animals of various species communicate. However, only a human can work with information simultaneously in different sign systems. Poly-lingual information activity is the most important feature of thinking.

Depending on what kind of elements create new orders, thinking operates in the symbolic and/or material world.Creating new orders from symbols reveals itself as a human language activity, which products are statements (sequences of signs in oral speech) and texts (sequences of signs in written language). In culture, this activity manifests itself in science, art, philosophy, politics, and religion, aiming to create new socially significant texts. Creating new orders from material elements occurs in the practical object-based activity. It results in physical objects with the required properties arriving. Practical object-based, sociocultural, and other human activity suggests creating information (new orders). From this perspective, any productive human activity can be seen as a mode of thinking. Indeed, the requirement for human behavior is awareness, a sense of purpose, soundness, and an action mediated by thinking. Languages, thinking, and practice form the three essential dimensions of human subjectivity.

Information activity determines the reason for human existence. Man exists in the universe to work with information, create new orders from symbols and material elements, thus enhancing the universe's orderliness. Shaping the ability to perform information activities is the goal of learning.

In school, developing skills like reading, writing, and counting, the child can assimilate information stored in texts. Children master languages (sign systems) and their grammars (sign-operating rules), both presented in the subject matter contents. They also learn to convert teaching information through the rules set by the science being studied and the methodology of its teachingwhile working on simple problems with ready answers. The child learns these algorithmic actions and operations with information as skills. In vocational education, students do no longer work with information in a symbolic form only. They learn to create orders from material elements through the practical object-based activity. In higher education, creative information professionally-oriented activitiesgrow in importance.

Education consistently builds the human ability to instrument the pivotal functions of information activity: receiving, storing, transmitting, processing, and creating new information. In pedagogical terms, this suggests transmitting knowledge (or information, in a subject-specific language) and building skills (operations, actions, and information processing methods in a particular working language). The advent of the computer markedly changed the nature of information activities and the learning environment.

Under the fifth information revolution, computers connected in networks effectively store, transmit, and process information by an algorithm. The real-time opportunities they provide are available to everyone. On the flip side, computers have one critical restraint: they can not produce new information bearing an objective value by themselves. In the information society, the functions of thinking (information handling) are differentiated between different actors involved in information activity: human-made information machines (computers) and their systems (networks), on the one hand, and man and social groups, on the other. Digital networks facilitate storing, transmitting, and information processing so efficiently that they are often referred to as artificial intelligence. Man more and more dedicates himself to the tasks of creating new information of social significance. With this functional differentiation, human thinking turns into an objective digital reality shaped by computer networks, which man interacts with, learns, and develops.

Prior to the digital age, schooling was about readying a human for reproductive work with information. The learning process followed the KAS (knowledge-abilities-skills) paradigm and offered the assimilation of a particular body of knowledge and operating rules to work with it. In the 1960s, learning objectives were radically revised. In 1964, E. Ilyenkov formulated the categorical imperative of new pedagogy: «The School Must Teach Thinking.» V. Davydov projected a system of developmental teaching aimed at shaping student theoretical thinking. M. Skatkin, I. Lerner, V.Krajevsky introduced a new structure of educational content: knowledge, skills, creative experiences, and emotional, value-based attitudes. The active modes of learning encouraging student brain building were developing and used on a massive scale. While retaining pedagogical and cultural significance, knowledge transmission and skill-building lost their self-sufficiency, turning into one of the functions of shaping readiness for relatively independent (within learning opportunities), productive, and creative information activity. The challenge of brain building became of immediate concern. Schooling had to ensure the progress of all brainwork functions, i.e., receiving, storing, transmitting, processing, and creating new information, none of them being ignored.

In the digital age, the economy, above all, formulates its demand for humans as the actors of such activities that information machines cannot perform. Shaping the individual creative thinking capacity for creating new information has become one of the principal pedagogical tasks. Essential strengthening of the creative component in human information activity under the fifth information revolution actualizes the question of how new information is created.

5.2. The Model of a "Conscious Object"

The solution to the problem that is objectively posed before education by the post-industrial and digital economy — the quality development of human thinking — lies in the educational modernization aligned with thinking processes. This task requires, first of all, a rational understanding of the algorithm for creative thinking. What laws underlie it? How is new information created? That kind of fundamental knowledge cannot come from anywhere but must be formed in a historically consistent manner and kept in authoritative scientific schools.The tradition that originates in Dostoevsky's polyphonic novels can be productive for the study of thinking. It received scientific embodiment in Bakhtin's theory of polyphonism (polyphony) and was further developed in Bibler's theory of the dialogue of cultures and Lotman's structural-semiotic method for cultural studies.

Ju. Lotman developed the model of a "conscious object" that may lay the methodological groundwork for the studies of laws governing the evolution of thinking in education. He views art and culture as "secondary modeling systems," historically superimposed over the "primary modeling systems" — languages. Their most important functions are to accumulate information and fight entropy. "We live, says Lotman, in a world of culture. Moreover, we are in the thick of it, inside of it, and that is the only way we are able to continue our existence... Culture is a device that generates information. Just as the biosphere uses solar energy to convert the inanimate into the living (V.Vernadsky), culture, relying on the resources of the world around it, turns non-information into information. Culture is the human anti-entropy mechanism. It can be addressed with the words of Heraclitus of Ephesus: "the Psyche, in which dwells the inherent self-growing Logos." Culture should have a complex internal organization for performing this task."[46]

The ability to create new information allows considering culture as the largest intelligent system known. Yu. Lotman defines three classes of such systems, or, as he also calls them, intellectual (conscious) objects: "man's natural consciousness (an individual human unit), the text, and culture as a collective intellect."[47]The "conscious object" is capable of the following:

"1) storing and transmitting information (by means of communication and memory), possessing language, and formulating correct messages;

2) performing algorithmic operations to correctly transform those messages;

3) formulating new messages.

Messages formulated according to the operations stipulated under point 2 are not new insofar as they represent nothing more

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[46] Lotman Ju. M. Selected Articles in 3 vols. Vol. 1. Articles on Semiotics and Typology of Culture. - Tallinn: Alexandra. 1992 - P. 9.

[47] Ibid P. 29.

than the regular transformation of the source texts in accordance with certain rules.In this sense, all messages received as a result of regular transformations of a given source text can be considered the same text… Operations related to the transformation of a message stipulated in point 2 occur in accordance with defined algorithmic rules.This means when the direction of the operation is reversed, the initial text is reproduced. Such textual transformations are reversible.To produce a new message required a fundamentally new type of system. We will define new messages as those that do not arise as the result of simple transformations and, therefore, cannot be automatically produced from an initial text through the application of previously established rules of transformation."[48]

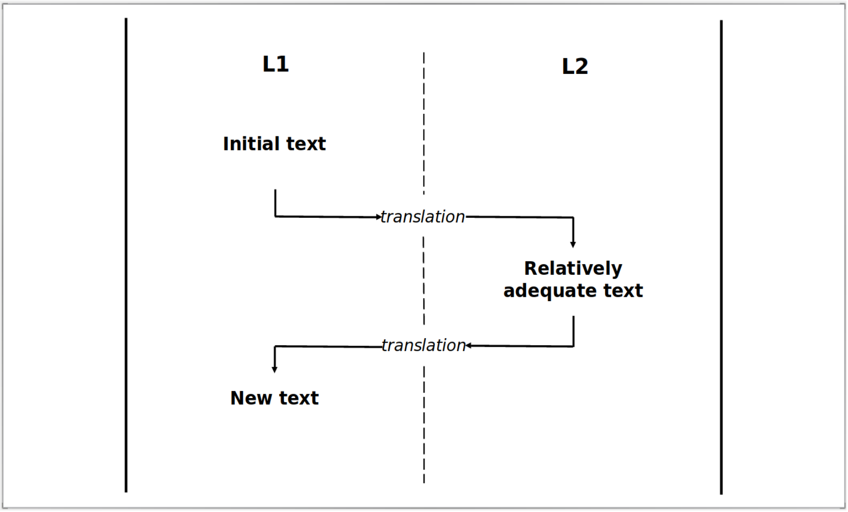
The ability to create new information is a defining characteristic of intelligent behavior. Not all systems that work with information have intelligence. A radio, TV, computer, and other information devices meet the first two conditions: receive, store, and convert information according to the defined rules. However, they are incapable of formulating new messages. If such devices do not work according to the rules established for them, the information they give out, such as hissing in the phone or a distorted image on the computer screen, is seen as a system failure. The computer can quickly process large databases, work with information much more efficiently than a man does, but it cannot think or create new information that matters to people.

Lotman's core demand for intelligent behavior helps to understand the restraints of traditional schooling and see why it does not work on student brain building. Transmissive learning based on knowledge reproduction is organized as a succession of steps: 1) knowledge presentation, 2) its assimilation by learners, 3) knowledge reproduction as initially presented by the teacher,

[48] Ibid P. 34 - 35.

4) knowledge application by a known algorithm for problem-solving to receive correct, i.e., already ready answers. This type of learning meets the first two conditions for intelligent behavior: to store, transmit, and convert information according to pre-set requirements. They are necessary, but not sufficient. If the student does not systematically create new information that matters to themselves, the teacher, and other students, then over the studies, the characteristic feature of intellectual activity that principally distinguishes it from storing, transmitting, and information processing is neither manifested nor shaped. Thus, transmissive learning based on knowledge reproduction does not have a notable and targeted impact on human brain building. The thought is shaped and refined throughout social engagement, and the school is just one factor out of many in this process.

Yu. Lotman developed a theoretical model of “conscious object.””Let us imagine two languages, L1 and L2, that are constructed in fundamentally different ways so that the exact translation from one to the other is generally impossible. Let us suppose that one of the two is a language with discrete semantic units having stable meanings and with linear sequences in its syntagmatic organization of text, while the other is characterized by non-discrete representation and spatial (continuous) organization of its elements. Accordingly, the dimension of content in these languages will also be constructed in fundamentally different ways. If we should need to transfer a text in L1 by means of L2, there can be no possibility of exact translation. In the best-case scenario, a text will be produced that, in relation to a specific cultural context, can be considered an adequate representation of the first.



Let us suppose we are dealing with translation from a natural language into the non-verbal language of nineteenth-century painting. If we then perform a back-translation into L1, we, of course, will not end up with our initial text. The text produced will be a new message in relation to the initial text. The structure of relatively adequate translations cannot be accommodated by either of the simple models of the creative intellectual process. From this, it follows that no cognitive structure can be unistructural and monolingual as it must include within itself linguistically diverse and mutually untranslatable semiotic formations. A necessary condition for any intellectual structure is internal semiotic diversity."[49]

Translation (relatively adequate translation by Lotman's definition) is a universal model of intelligent behavior. The more semiotically diverse target languages are, the higher the potential of mental activity is, the more unconventional a newly formulated text can be.

"At all levels of cognition, from the two hemispheres of the human brain to culture at every structural level, we can discover

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[49] Ibid Pp. 35-36.

binarity as the minimal structure of the semiotic organization... Observing the bipolar organizing structure at the most diverse levels of human intellectual activity, it is possible to isolate oppositional pairs, with discrete linear thinking predominating along one axis and homeomorphic, continuous thinking along the other, and to establish a parallel with the opposition of the left and right hemispheres of individual cognition.

Children's consciousness	⟷	Adult consciousness
Mythological consciousness	⟷	Historical consciousness
Visual consciousness	⟷	Verbal consciousness
Action	⟷	Narrative
Poetry	⟷	Prose

This system could be extended to include similar oppositions. It is important to emphasize the value of isolating the level of semiotic apprehension of the world for it is at that level that the organizing opposition becomes evident, which can then be situated within the adduced series. Without that opposition, the given semiotic mechanism is devoid of any internal dynamism and is only capable of transmitting information, not creating it."[50]

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50 Ibid P. 38.

5.3. Giving Rise to Mental Activity

The cognitive process occurs by continuously translating meanings into different languages created (historically or artificially) to perceive the world around. It is impossible to think in one language. The elementary and extremely technological formula for thinking is as follows: *thought is translation*. The more languages are involved in translation, and the more they differ, the deeper and more productive thinking is. The subject of thinking (the thinker) must be continuously involved in the changing social and cultural relations, in communication with other people — native speakers of other languages, which requires consistent transitions from one semiotic space to another.

Translations are the bedrock of all levels of intellectual activity. The brain is the biological organ that is the origin of thought for a person. The brain cortex has a pronounced functional asymmetry. The left hemisphere is responsible for speech, logic, and abstract thinking. The right one is associated with visual-imaginative, concrete thinking, word denotations, recognition of vocal intonation, melodies, and rhythms. The brain hemispheres have different semiotic specializations: the left one works mainly with discrete sign systems, the right one with non-discrete languages. There is constant information sharing between the two, which, due to the different semiotic specialization of hemispheres, is translation and acquisition of new information. All communicative situations are similarly structured. The simplest form of mental activity — conversation — takes shape as a translation of inner speech into outer speech and vice versa (a dialogue with yourself) and a translation of messages from one person's language profile to that of another. The communication process flows as a succession of translations delivering new information and causing interest in productive communication. As additional linguistic tools for enhancing semiotic diversity of the communicative situation and effectiveness of translations, talk partners can include emotions, associations, memories, and other neuro — and psycholinguistic forms of information coding in their communication.

Thinking occurs in communication, in the interaction of different linguistic actors in all cultural areas, the “natural habitat” of thought. Just as life forms can exist only in the space of life — the biosphere, so subjects of thinking (thinkers) can act, communicate, and create new information only in complex linguistic and text spaces — cultures. “Any culture is semiotically heterogeneous, and a constant exchange of texts is taking place not only within the semiotic structure but also between structures of different nature.This entire system of text exchange can be broadly defined as a dialogue between disparate but being in contact text generators.”[51]Culture is divided into many different linguistic spaces by internal fluid boundariesbetween which text exchange processes are constantly taking place. Due to semiotic heterogeneity and the ongoing activity of different language bearers, culture itself is a powerful generator of new information. There are three key methods for boosting the information productivity of culture and its actors: integrating cultures into multiculturalism, the “semantic explosion of culture,” and the development of cultural forms by increasing their semiotic heterogeneity.

The first one is being implemented against the backdrop of globalization. It brings cultures closer together, increases the thickness of their outer and inner boundaries, and develops their semiotic heterogeneity. Globalization pulls cultures out of the state of relative closure unnatural for any semiotic system, enhancing their capacity to produce new information. Culture starts to work as a powerful socially organized generator of texts continuously transmitted to the open universal cultural space — the semiosphere — the planetary envelope of signs surrounding the Earth.

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[51] Ibid P. 49.

The concept of the "semantic explosion of culture" belongs to Ju. Lotman. Widely, it means a semantic intersection, "connecting the unconnectable under the influence of some creative tension,"[52] turning the untranslatable into the translatable, which causes a sharp increase in the information content of the entire system. In a precise sense, it is the historical moment when culture meets itself. The most striking example of this is the Renaissance, "connecting the unconnectable" — ancient and medieval semantics, which caused a creative "explosion" of European culture.

The third method of enhancing mental activity suggests fashioning cultural forms via "semantic intersection" by expanding the possibilities of inner translations. Pedagogy has accumulated considerable experience in employing this method. Let us consider the latter on the examples of some didactic principles implemented.

Using visual aids is the simplest and best-known technique of giving rise to student mental activity, enhancing awareness, and strengthening learning. The didactic principle of using visual aids involves acquiring knowledge by observing real-world objects or substitute images and models.It entails a particular form of methodical organization that, besides the verbal description of an object, employs its visual image presented as a real-world object, model, or artistic image. First, the student reads a given text verbally as a sequence of words and sentences that form a systematic, rational idea of the object; then, the same content is translated into another language, simpler and easier understood by the student — visual images. This principle suggests that two languages are simultaneously at play within a given learning situation — a discrete language of the teaching text and a continuant (non-discrete) language of the visual image.The use of visual aids has always been a table-top effective method of raising learning awareness, and J. A. Comenius proposed that all learning be based on it.

[52] Lotman, Ju. M. "Universe of the Mind: A Semiotic Theory of Culture". - Saint Petersburg: "Art-SPB", 2010. P. 27

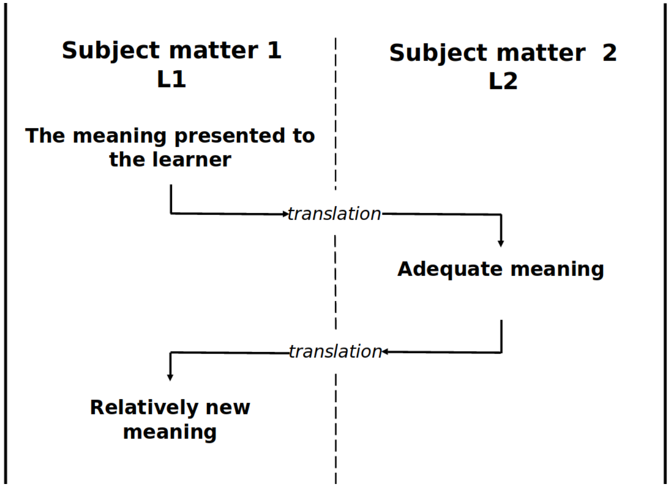
Another method for provoking thinking is to combine theory with practice. Its algorithm is the same as that of visual teaching: knowledge about what is being studied (object, regularity, event, a form of action, etc.) is first presented in the language of science in the form of a sequence of words-notions, and so is read by the student, then the system of meanings is recoded into the language of real-life actions. The student can put into practice what they previously knew only in theory. The connection between theory and practice is, in fact, a translation of educational content from the language of subject-based learning into the language of actions in the real world.

The use of visual aids and connection between theory and practice are the classical didactic maxims. They have different forms of implementation. It would be right to speak about real-world natural examples (plants — in biology lessons, chemical reactions — in chemistry lessons, etc.), the imagery (posters, diagrams, etc.) and wordy metaphoric description (emotionally vivid, imaginative descriptions of the objects and events under study, etc.). The connection between theory and practice is accomplished through laboratory and practical experiences, excursions, project activities, observation of various objects and phenomena by employing active forms of cognition (diary of observations, measurements, etc.), educational-labor and vocationally oriented activities. However, their capacity to enhance thinking is limited. They have local methodical application. Not all scientific knowledge can be adequately translated into the language of visual images and simple practices.

Generally speaking, traditional subject-based learning hinders brain building. According to Lotman's theory, "no cognitive structure can be unistructural and monolingual," but any subject matter is a "unistructural and monolingual" didactic system. Physics is taught exclusively in the language of physics[53], biology — in the language of biology, etc. Each academic subject is methodically self-sufficient in its monolingual nature. In knowledge-based didactics, the learner creating new information is not seen positively: the child should not and cannot create new knowledge. The emergence of new, methodically non-programmed information is considered an error. Learning based on knowledge reproduction falls short of a proper learning environment for student brain building.

In the 1960s, when the task of enhancing student brain functionwas being addressed, the means to achieve it came to the fore. At the onset of the information age, the technology of inter-subject communications was developed and tested experimentally. It overcomes the monolingual aspect of academic subjects while fully preserving the entire mode of subject-based training. Each interdisciplinary relationship creates a learning thought-provoking situation and translates a particular meaning from one subject-specific language into another. Inter-subject communication, bridging similar meanings from two or more subject matters, is a poly-lingual didactic construction. Immersing into this environment, the learner can do relatively adequate translations and receive new information.Thus, a local "conscious object" springs up — a methodically organized construction that allows the learner to master the subject matter solidly and at a highly conscious level and create new additional information based on it, such as new rationales, personal experiences, comprehension, and value-based attitudes.Inter-subject communication — "conscious object" — is an elementary didactic construction that encourages personal fulfillment in the teacher and the learner, both being actors of independent thought and productive information activity. Let us see how this construction works with a model.

[53] Developmental learning within the subject "physics" is possible if taught and studied in the languages of mathematics, history, astronomy, chemistry, etc.

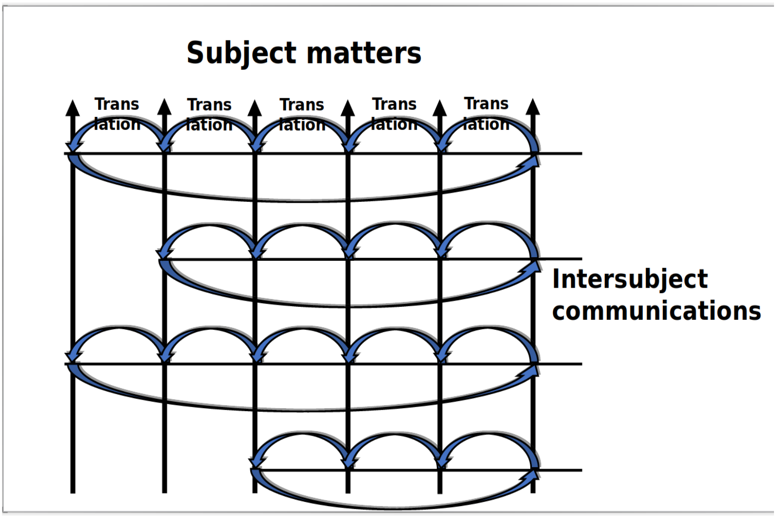


Semiotic model of inter-subject communication

Setting up an inter-subject communication begins with a given content (meaning) of subject matter 1, currently being studied under the curriculum. This is a standard pedagogical task: the learner is presented with knowledge, and it is necessary to ensure that he acquires it solidly and at a high level of consciousness. Tackling the task is challenging while remaining within a single subject matter due to its monolingual nature. An interdisciplinary connection is necessary. To establish it, one should find such a meaning in the content of subject matter 2 that is similar to that of in the content of subject matter 1. There are similar meanings in all subject domains, as Nature is one in its essence and manifestations. Sciences and arts use their specific languages to think in diverse ways about particular areas of a whole Nature. Therefore, each real-world object is reflected uniquely in the semantic spaces of many sciences and arts.The inter-subject communication familiarizes educational subjects with one or more meanings of the same object (manifestation, process, quality, phenomenon) of nature (material, social, intellectual, spiritual).Studying a given meaning in L1 is subject-based; the other meaning, in L2, serves to give sense to the first one.When such a connection is established, a mental translation of the meaning from L1 into L2 and vice versa occurs. Since these languages are fundamentally different, translation cannot be a mere reproduction of the teaching information initially presented to the learner.A relatively new meaning emerges; it complements the original meaning and results from its comprehension by the learner. Through translation, each inter-subject communication didactically ensures the creation of new (relatively new) information. Presenting this information back to the teacher shows that the student has consciously mastered the subject knowledge and is capable of applying it beyond the boundaries of the given subject.

5.4. Artificial and Natural Intelligence in Learning

Systematic inter-subject communications based on subject matters form a decentralized network of educational content, permitting relatively adequate translations with no limitation. Let us present its theoretical model.



Model of networked interdisciplinary translations

In the network of educational content with fully preserved traditional subject-based learning, vast opportunities for brain building of both teachers and learners open up. Inter-subject communication is a sequence of translations of a given meaning from the language of one subject matter into the languages of others. Since the languages of science and art, as well as of the other forms of social consciousness, being the most potent tools of thinking, specialize in the cognition of physical, biological, and social nature, whereas the corresponding subjects recreate their semantics, the network of educational content can be seen as a workable form of artificial intelligence, producing new objectively meaningful information about the world.

The network of educational content rests upon the principles of the human nervous system functioning. This is well seen in the model. Inter-subject communication is similar to a synapse.[54] The latter is a junction between two nerve cells (neurons). The synaptic transmission adjusts the amplitude and frequency of the transmitted signal. Similarly, inter-subject communication ensures the matching of two closely related meanings from different subject matters and, while translating, methodically regulates their semantic parameters (the perception pattern, student comprehension depth, etc.). The specific meaning itself is akin to a neuron — a structural and functional unit of the nervous system.Meaning (a scientific notion, theory, artistic image, etc.) is a semantic unit of the content of education. Its conscious assimilation by the student is the primary function of teaching and learning activity. Just as a neuron is connected to other neurons, the meaning within a subject matter is methodically related to those meanings that have already been and are yet to study, as well as to the meanings of other academic subjects. Inter-subject communications supplementing intra-subject ones make up a full-fledged network structure.

[54] Synapse - Greek σύναψις, from συνάπτειν - connection, communication.

Neuron connections build up biological neural networks. They are called “wet networks”. Intra-and inter-subject communications, connecting the components of cross-curriculum content, shape a network of educational content. This network belongs to the class of “dry” artificial neural networks built on the principles of biological neural networks and based on mathematical models that can solve big problems and self-learn. The artificial neural network of educational content is filled with meanings representing the culture and recreating the history and logic of human thought evolution. Alongside this, its didactic basis reconstructs the processes of thinking. Unlike all existing artificial neural networks, this one technologically reproduces the unity of conceptual and procedural dimensions of human thinking in the cultural context, thus making digital education the most promising direction for the further artificial intelligence development.

Let us consider the possibilities of an artificial neural network of educational content — a pedagogical model of artificial intelligence (AI) — for enhancing student thinking. As an example, we take the study of the mathematical concept “a set” in primary school. First, let us picture a typical learning situation when training suggests a teacher-student interaction with natural intelligence involved.

The teacher faces the task of explaining to the younger schoolchild that there is a “set” as such. This notion is of pivotal importance in mathematics; due to its fundamental nature, it cannot be reduced to other notions (ideas) and is, therefore, difficult to define. A German mathematician Georg Cantor gave a classic definition: “A set is an arbitrary collection of definite well-distinguished objects, mentally united into a single whole.” This definition is studied by children in a primary school in a math lesson. It is extremely abstract, and its meaning is not easy to grasp. To understand something means to comprehend it in the context of life and available forms of activity. What is the meaning of a set? What is its importance to human life? What role does it play in organizing human activities? What new opportunities does it open up for thinking and behavior? Answers to these and other questions are almost impossible to get, remaining within the boundaries of mathematics. The intellectual interaction of a math teacher and a primary schoolchild prevents them from answering those questions. Often cited examples of a set, like "a set of pencils in a box," a set (species) of coniferous trees, add little to comprehension. Instead, they lead to the idea that you can do without this notion: the pencils in the box will not disappear, and the trees in the forest will remain, if not knowing they constitute the "sets." In class, as a rule, the matter comes to a compromise: let the child first remember, and then somehow comprehend. Using only possibilities of natural intelligence of both teacher and student does allow no grasp of the notion of a set at a highly conscious level, nor does the child understand what it is about and why one should need it. While learning, the schoolchild's independent thought is not provoked, but mainly their memory works. A lack of potential for personal mental activity makes any study boring.

Let us change the conditions of the mental experiment. Let us imagine the same problem but addressed in the artificial neural network of educational content. The capabilities of natural intelligence go beyond when interacting with AI. Three main things account for the pedagogically organized AI:

• A database of multidisciplinary knowledge generated by the network of educational content;

• A learner — a subject of education with natural intelligence;

• An intelligent interface that allows the learner to interact with networked content. The teacher is responsible for this interaction. The teaching techniques define the software tools and rules for descriptions, agreements, and behavior protocols.

After coming to know the notion of a set in a math lesson, the learner, with the teacher's assistance, "goes" to the network of educational content. They search for and find notions nearest in their meaning to the mathematical notion under study. And it is easy to find in informatics. Because the languages of mathematics and informatics are similar, the meaning of a "set" will not differ significantly. Thus, in informatics, it is defined as a cluster (group) of elements that have common properties. Knowing this does not help understanding. There is a need for a thought-provoking language radically different from that of mathematics.

Following the mathematically defined characteristics of a set, finding this notion in another subject matter — a native language — is also possible. In linguistics, as in mathematics, it is fundamental. The set is an alphabet — a set of alphabetic letters. The sets are vowels, consonants, punctuation marks, language vocabulary, etc. Why do these sets exist? Words, sentences, and texts are formed from multiple linguistic sets under the rules for speech activity. Every particular sentence is an intersection of a large number of linguistic sets. For example, every word is a set formed from the elements (linguistic signs) of two (consonant and vowel) sets. The elements of various sets enter the space of a word, sentence, or text according to the defined rules and create their (word, sentence, text) real meanings. If a language did not consist of many abstract sets, speech activities would not be possible.

To consolidate this new, concrete understanding of the set, let us continue the inter-subject communication using the domain of "art." What fundamental sets exist in painting? The artist creatively recreates objects expressing their essence through the play of light. Paints are the artist's tools. Each group of dye-ware is color-bound and can be seen as a set of elements. The artist mixes paints, gets new colors and shades, and applies them to the canvas. A picture is just an intersection, a superimposition, a combination of different color sets in formal terms. A real object is recreated with their help, and its meaning is revealed as an artistic image.

The network-based (inter-subject) approach to teaching information breaks new ground for its broader understanding. The inter-subject communication "mathematics — a native language — art" gives substance to the initially abstract presentation. The child absorbs the meaning of the notion "set" as one of the most mattering human activity categories. To create something concrete, various sets must be connected. Everything that is single-concrete stems from the merging of the diverse-abstract. In this learning situation, the younger schoolchild quickly masters the essence of the complex philosophical principle and research technique by ascending from the abstract to the concrete. To say something, one must arrange signs from different linguistic sets. To cook the soup, one must combine, in a recipe sequence, ingredients from different sets: vegetables, spices, herbs, etc. The set is one of the most important notions for the activity.

Pedagogically organized interaction of the child's natural intelligence and the intelligent network of educational content helps create new meaningful information. For instance, now the child can consciously find an unconventional answer to the question: what is an empty set? It could be as follows: "An empty set is a place where many sets can intersect, and something concrete can appear as a result." Or it could be in a very childish way, but with the exact meaning: "When I imagine an empty set, I know for sure that something can appear here, in this place, and I know how it appears." An empty set is a place of creation. The method of creation implies combining elements from various sets by the actor of activity.

Working in the network of educational content built on AI models ensures the qualitative development of the learner's thinking.He comprehends the notion of set, creates new information that has pedagogical value and testifies to his own proactive mathematical thinking. No less important is the fact of awaking interest in mathematical notions. The child realizes how vital these notions are to man: nothing real can be created with no mastery of sets. The meaning of Pythagoras's words falls into place: "Reducing sets to one whole is a primordial nature of Beauty."

The translation process, which involves the re-coding of meanings from one educational language to another, is not only a method of sound and conscious learning but also the very principle of thinking. The coherent content of digital education and its didactic organization built on modern information technology (artificial neural networks) helps implement this principle and ensure student brain building.

Chapter 6. Digital Integrative Learning Module

6.1. Modular Organization of Digital Education Content

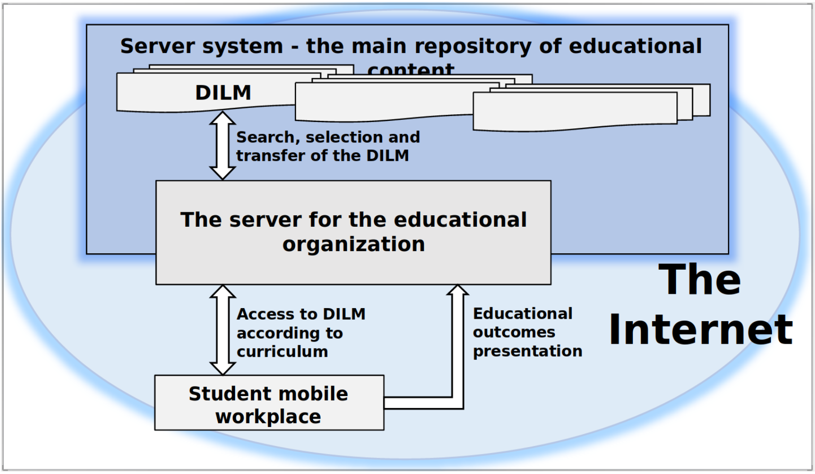
The idea of the coherent content of education embodied in the unity of subject matter and interdisciplinarity is well known. Dozens of books have been published on interdisciplinarity, hundreds of dissertations have been defended, and extensive practical experience has been accumulated since the 1960s. Every teacher is well aware of cross-curricular linkages potency to assimilate knowledge at a highly conscious level, increase the interest in learning material, and enhance independent student thinking. The teachers do not doubt their relevance and potential for the further development of education. Practically, it is impossible to integrate multidisciplinary content without modern digital information technology. Extensive pedagogical experience of the 1970s-1980s showed that tracing and applying inter-subject communications by subject teachers faced great difficulties, mainly of technical nature. Inter-subject communications are complicated to use in an environment with educational content stored on paper, with its manual processing. When there is a need to apply them systematically, teacher qualification requirements increase substantially and begin to exceed their professional capabilities. The teachers are bound to become proficient with the content and languages of other subject matters on their own and find new methodical solutions to the most complex interdisciplinary problems in the constantly changing landscape of learning.

The contradiction between the vast learning opportunities of intersubjectivity and the real conditions and modes of teacher activity (work hours, professional readiness to teach a single subject matter, high psycho-emotional load, the limited and selective capacity of human memory, etc.) is resolved by digital educational technology. It paves the way for the networks of educational content to be created in the unity of subject matter and intersubjectivity. ***A Digital Integrative Learning Module(DILM)*** may become a form of combined application of digital educational technology.

DILM is an electronic stand-alone organizational- and methodical block of the curriculum, which includes thematically defined and methodically organized subject-based content of education and a corresponding system of inter-subject communications.Within its boundaries, both traditional pedagogical tasks (transmitting knowledge, building skills) and those dictated by the digital economy are addressed: gaining creative experience, brain-building, enhancing an emotional, value-based attitude toward the subject matter under study, shaping skills for creating new socially significant information on the ground of objective scientific knowledge.

DILM is a critical organizational unit of digital education content. It covers the study topic of a given subject matter as part of the core curriculum. The study topic is an integral part of the subject matter content. It presents a minimal piece of content necessary to organize a full-fledged learning process. The study topic sets the boundaries for the digital learning module: one topic — one module. The sequence of modules reproduces the sequence of study topics in a particular curriculum.

Information technology, information-processing hardware, information- and telecommunications networks support digital education activities and send integrative modules via the Internet. Let us imagine a possible scheme for sending modules.



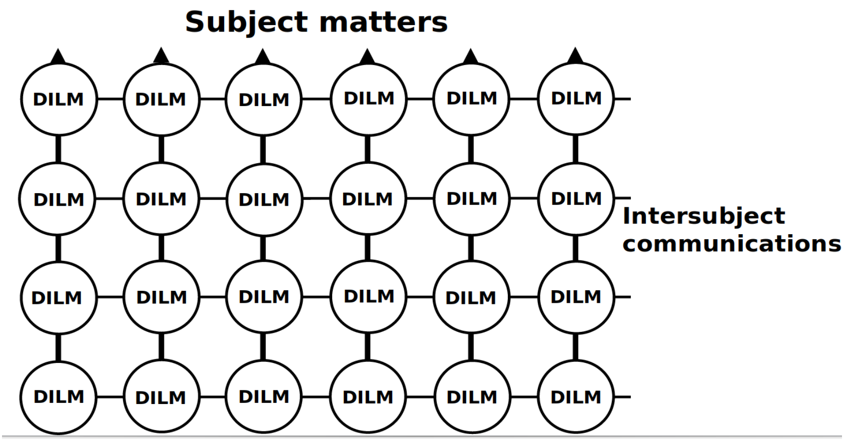
Scheme of storage and delivery of digital integrative learning modules

The entire educational content can be stored on servers that make up the master repository of electronic educational resources. The master repository registers, catalogs, and accumulates DILM modules structured by curricula and learning levels. It also facilitates the search and delivery of DILM modules to the student's place for study. This place is easy to change, and it depends on whether the learner has a computer at school or home, a tablet, or a smartphone. The learner receives the module and works with it in a suitable place at a convenient time.

The electronic scheme for storing and sending modules is a well-tuned system of online services for distance learning. Also, the DILM module itself does not yet differ from the digitized content of the study topic. This means that the technological basis for the school of digital society has mainly been formed and tested over the decades of informatization of education. The content has been digitized, thematically structured, and the system of distance learning has been developed. With that, new-quality learning relationships, processes, and outcomes have not yet been achieved. The DILM module offers simple technological solutions that can empower the change in learning.

Its primary difference from the digitized topic section of the curriculum is that the DILM module contains the digital content of study topics, including inter-subject communications that cover the study topic through other subject matters, practices, and types of activity. The teacher and students receive a content-ready and methodically developed system of subject-specific knowledge and a corresponding system of inter-subject communications. This essentially expands the semiotic space of the module and opens up opportunities for translating the meanings of the study topic into languages of sciences, arts, and other forms of social consciousness. The DILM module is a pedagogically organized "conscious object". Within its boundaries, subject matter and intersubjectivity complement and enhance each other's learning opportunities.

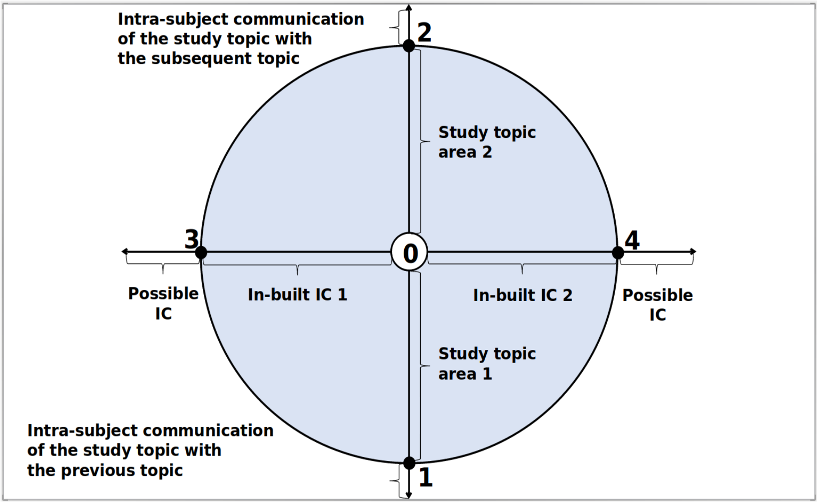
Digital integrative modules are quite simple organizational elements that make up a single network for educational content. They take shape at the intersection of subject and inter-subject lines and structure the entire content of education, technically ensuring its organization on a network basis.



Modular model of the content of digital education

The Digital Integrative Learning Module appears to become a dominant mode for organizing digital education content on a network basis due to its capacity to combine subject matter and intersubjectivity and meet multiple modern pedagogical challenges. The DILM is a basic working mechanism of a decentralized network for educational content.

Let us enlarge the modular model of the content of digital education and consider the overall structure of the DILM.



Model of the overall structure of a Digital Integrative Learning Module

This model gives an idea of the internal structure of the DILM module and how it is linked with other modules.

Segment 1-2 indicates a given study topic related to the subject matter in the core curriculum. Dividing this segment into smaller ones — 1-0 and 0-2 shows that this study topic is methodically structured, divided into sub-themes, and other methodically related content fragments. The existing teaching technique for a subject matter remains unchanged in the integrative modules. This is crucial since it shows the continuity of innovative (digital and integrative) and traditional (analog and subject-based) learning.

The DILM structure seamlessly and strictly rationally combines subject matter (a vertical line) and intersubjectivity (a horizontal line).

Segments 3-0 and 0-4 indicate the inter-subject communications (in the diagram — IC) built in the module. Their number may vary, but it should be sufficient to master the subject-related topic strongly and at a high level of consciousness and competence — the ability to apply subject-specific knowledge beyond the boundaries of the subject matter.

The vectors coming from the extreme points of the model also have their meaning. The vertical vectors starting at points 1 and 2 show that the study topic is related to the previous and the subsequent ones within the module, this ensuring the classical principles of scientific rigor, systematicity, consistency, and accessibility. The horizontal vectors coming from points 3 and 4 show the possibility of adding to inter-subject communications. The module has already had built-in cross-curricular linkages. Still, the network also contains potential (relating to the study topic) interdisciplinary relationships that can be employed and integrated into the digital module by educational subjects themselves. Theoretically, the IC sequence can be as long as desired and nonlinear, linking the content components of one subject matter with the content components of other subject matters.

The "0" spot also has a specific meaning. It indicates the beginning of a digital (numerical) row, the only digit that denotes not the number (quantity) but its absence, and, therefore, its pure possibility. Nil is emptiness, nothingness, the absence of certainty and meaning, and yet the basis of any quantitative certainty — the "empty set" in mathematical terms. In digital reality, everything starts from nil. In the DILM model, nil is not shown as a dot, as usual, but as a small circle at the intersection of the subject and inter-subject lines. The circle symbolizes a particular content area where subject knowledge in the language of the corresponding scienceis combined with similar-meaning knowledge in the languages of other sciences, arts, forms of consciousness, and activity. In the “0”area, it is possible to achieve a deeper level of thinking than traditional training can support by combining subject matter and intersubjectivity. The new content of integrative thinking one can define in various ways: as “knowledge before knowledge” (Socrates), sense (Gilles Deleuze), personal meaning (A. N. Leontiev), personal knowledge (M. Polanyi). At the level of integrative thinking, man possesses the ability to know something beyond any rational knowledge that cannot be expressed in language. Meaning is the basis of thinking, its quintessence, the reason to live and act. The true meaning will stand revealed in translation when a given meaning expressed by means of a given language will break free of its tangible sign envelope and for a moment — and this moment is the very transition through the “nil” area — will turn into pure meaning with no language, into content with no matter. A technical possibility to separate the content of a notion from its linguistic form is inter-subject communication. While translating meaning from one language into another, the replacement of a language form occurs naturally: the old one is no longer there, and the new one is yet to emerge. At the moment of transition from language to language, the meaning is stripped of any linguistic envelope, and pure essence comes up. The duration of intellectual observation of pure essence, or meaning with no language, depends on the gap between a source and target languages: the more “untranslatable” languages are, the more they differ in their logical and semantic organization, the bigger the volume of “language cleared” content can be obtained in translation, the more profound and exciting the thought, but the more challenging the labor of thinking.

The circle in the center of the DILM model at the intersection of subject matter and intersubjectivity represents the area of pure essence derived from translation. The content of contemporary education in the context ofthe information revolution is overflowing with knowledge, with teachers and students constantly experiencing a lack of the meanings (rationales) to master it — “Much learning does not teach nous” (Heraclitus). With no reason, man can neither live nor create. Human thinking, according to A. N. Leontiev, has a semantic structure. Thinking employs knowledge as objects, conditions, and tools. Its real purpose is meanings that fill thought with content and are instrumental in switching from one knowledge to another and consciously processing information in real-life contexts. Meaning is crucial for creating new information — ensuring orderliness in thinking itself, life, and the world around us.

Creating the DILM module is a key technology challenge in the transition to digital education. Its pedagogical functions are similar to those of creative information activity:

1 presenting knowledge (receiving information);

2 memorizing knowledge (storing information);

3 absorbing knowledge (recognizing, decoding, deriving meanings from the information received);

4 shaping abilities and skills (using the information to tackle problems);

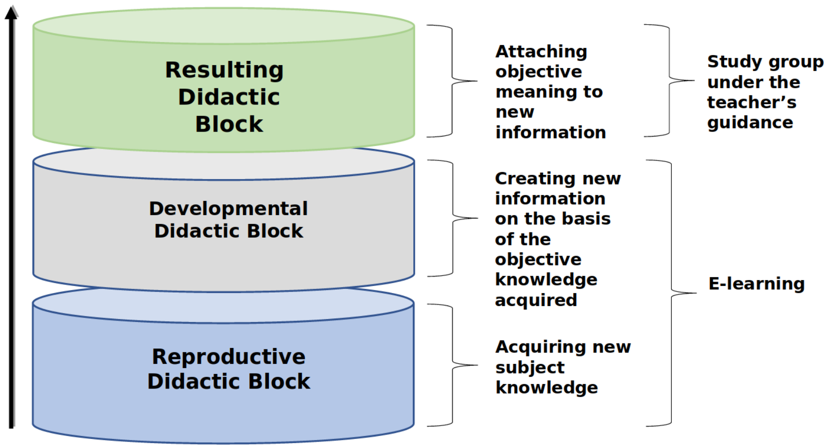
5 setting up and applying inter-subject communications for deep insight into knowledge (creating new information on the ground of the data obtained);

6 enhancing student brain building as a creative actor of the learning activity (accumulating and systematizing new self-received information).

A specific organizational structure of the digital integrative module ensures these functions to be performed. It consists of three didactic blocks[55]: 1) reproductive, 2) developmental, 3) resulting.

[55] Industrial production and construction activities use the term “block” to refer to a product, all parts of which are assembled in advance at the manufacturer and are mounted with other blocks on sight at the right time. In this sense, “block” is synonymous with the “node” notion. Also, this term refers to a simple mechanism to regulate force for doing work. A general idea of the “didactic block” notion corresponds to these plain meanings.

The DILM module is assembled from stand-alone didactic blocks. Each block pursues its own set of learning objectives. Moving from block to block, the nature of learning activity changes markedly — the didactic blocks regulate the mental activity of educational subjects readying them for efficient information handling.

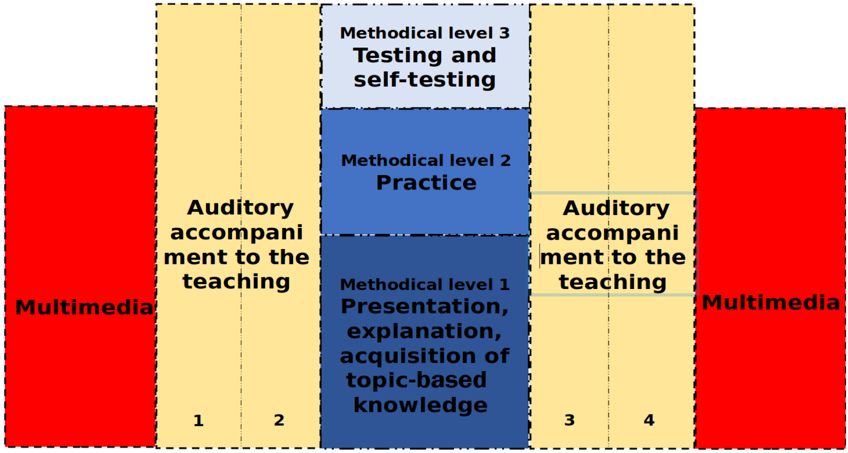


Compositional and functional model of a Digital Integrative Learning Module

The names of the blocks directly indicate the enlarged pedagogical tasks that each of them tackles: 1) mastering objective subject knowledge at the level of its reproduction and addressing sample problems, 2) comprehending reproductively acquired objective meanings by translating them into languages related to other subject matters, provoking personal thinking and creating relatively new information using the subject knowledge gained, 3) managing the product of learning activity — relatively new information for attaching objective meaning to it.Let us consider one by one the structure of each block and the organization of learning activities within their boundaries.

6.2. Reproductive Didactic Block

This block is a basic component of the DILM module. See its model below.



Model of Reproductive Didactic Block in the DILM module.

The didactic block derived its name from the notion of "reproductive learning (learning based on knowledge reproduction)." Within its boundaries, digital information technology transmits scholarly knowledge. As known, the basis of traditional reproductive learning is a standard methodical cycle: 1) knowledge presentation to the learner, 2) explanation, 3) acquisition, 4) consolidation, 5) learner's presentation of the knowledge acquired back to the teacher. The Reproductive Didactic Block puts the cycle into practice.

This block, as well as the next following Developmental Didactic Block, works as an "E-Learning" mode — making use of the Internet, multimedia, and the auditory accompaniment to the teaching. The learner conveniently self-masters the learning material, time and place personally chosen, creates and uses available social networks for learning purposes, and, if necessary, additionally and individually obtains the teacher's advice. The instructor's location can be geographically remote.

The Reproductive Didactic Block is divided into three consecutive organizational- and methodical levels. The first level is responsible for the presentation, explanation, and initial knowledge acquisition. Everything looks like in existing e-learning systems, but with significant additions.

For absorbing the study topic content, the learner needs the teacher's assistance. The teacher delivers, explains, repeats the explanation if necessary. Also, if understanding is difficult, the instructor presents the learning material in a different way, gives examples, i.e., does everything to make the topic content clear to the learner. In traditional schooling, the teacher usually applies this teaching technique at a lesson with limited time and being influenced by numerous distractions, with no real opportunity to explain the material to every student as they might need. The digital module eliminates these issues. At the stage of its development, the auditory accompaniment to the teaching is recorded, the teacher's explanations are pre-mounted in the digital module. Self-studying a topic, the learner turns on the "teacher's voice" if clarification is needed.He can listen to the explanations all the way through, selectively, or repeatedly, with or without breaks — up to the learner. A new topic always has difficult parts that require more comment. But these comments are different for each student. To help the learner acquire new material and successfully tackle all the difficult questions, the auditory accompaniment should be multi-layered and redundant, with one topic explained by different teachers and in different ways. The learning module must contain several variants of auditory accompaniment. The model shows different audio tracks 1, 2, 3, and 4. The learner has the opportunity to choose the option that suits him best. If necessary, he can listen to explanations of different teachers, compare all, and find what they have in common — the heart of the matter delivered in various ways. The most experienced teachers do the voice-over. It comes as a result of thoughtful collective work, the content regularly updating. The auditory accompaniment ensures consistent, high-quality teaching during the learning process, which is not always achievable in lessons.

To enhance opportunities for self-mastery of new material in the Reproductive Block of the digital module, a wide variety of multimedia visuals comes in. It suggests transmitting information simultaneously in different coding ways: text, sound, animated computer graphics, and video. The learner's main problem with understanding new material in the paper textbook has nothing to do with its complicated nature. The point is that the textbook information is delivered in one way — verbally, and in one language — the scientific one. Multimedia visuals present the same content but in other languages making it imaginative, aesthetic, dynamic, storytelling, and, ultimately, accessible and engaging. Modern digital tools allow modeling the phenomena and processes under study, experimenting with them in virtual spaces in an interactive mode, making virtual excursions, etc., which considerably facilitates the assimilation of the learning material.

Gaining new knowledge occurs in a comfortable environment. The teacher is freed from repeating the same topics from year to year, from grade to grade. "Smart" digital automation does the work. All the teacher has to say to the student explaining a new topic is presented at a high-level delivery with excellent-quality multimedia visuals. In this setting, it is the learner who organizes the self-mastery of new material. The learner finds the right time and a convenient place, sets the pace of learning, identifies the baffling parts of new content, and the way to tackle the problems: repeating the material in an optimal learning mode, remotely addressing the teacher for assistance, taking communication- and learning opportunities of social networks, etc.

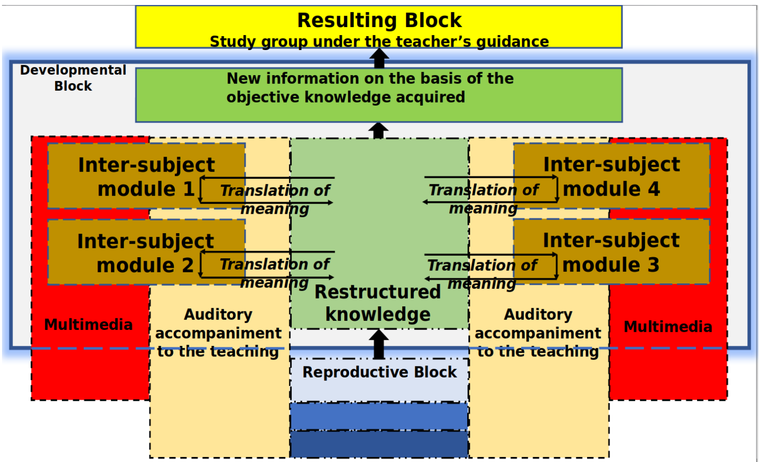
The second methodical level of the Reproductive Block is practice. This block allows consolidating the knowledge gained through achieving training tasks, performing laboratory-based and practical works in the virtual environment. At this level, knowledge turns into skills by applying them within the subject matter being studied.

At the final third level of reproductive mastering of the topic's content, the student has the opportunity to test himself by doing training-type control tests. Then he proceeds with doing final tests.

The specific feature of the summative assessment within the Reproductive Block is its overall automation. Tests are checked and processed automatically, and final results are sent to the teacher's computer. In networked learning, the academic performance rating is not the final stage of the learning process. On the contrary, digital education per se begins when the learner has already mastered the subject knowledge. The Reproductive Block is just one of the three blocks of the DILM module. This fact reflects the generic nature of digital education when acquiring ready-for-use knowledge is crucial but not an outcome of the learning activity. The knowledge gained does not indicate the completion of learning activity within a given study topic. Instead, it becomes a reliable and proven tooling for further productive thinking. With no knowledge gained, the student cannot come over to the Developmental Block of the DILM module.

6.3 Developmental Didactic Block

This didactic block model is connected with the preceding (reproductive) and following (resulting) blocks.



Model of the Developmental Didactic Block in the DILM module

The core of the second didactic block comprises the restructured knowledge related to the study topic. The content of restructured knowledge does not differ from the studies within the first block. However, its methodical structure changes. The learning material in the Reproductive Block is organized consistently and systematically: the complex is derived from the simple, the subsequent is based on the previous, information on the topic is presented in the logic of the corresponding science. In passing from the first to the second didactic block, the pedagogical tasks and the mode of organizing the learning process are markedly renewed so that the student could delve deeply into the knowledge gained, make it a subject of his own thinking, and carry out his solo intellectual activity. The tools of this activity are inter-subject communications.Its product is new (relatively new) information received by the learner while translating subject knowledge into the languages of other subject matters.According to these new tasks, the knowledge within the boundaries of the Developmental Block is arranged in such a way as to facilitate relatively adequate translations.The guiding didactic principle of organizing educational content in this block is intersubjectivity: certain knowledge on the study topic is integrated with close-in-meaning knowledge from other subject matters. Inter-subject communications are developed in advance and incorporated into the Developmental Block as stand-alone inter-subject modules. Let us look at the functions such a module performs both in and out of a given DILM module.

The substantive basis of the Developmental Didactic Block is shaped by inter-subject communications that integrate the topic-specific knowledge with close-in-meaning knowledge from other subject matters.Inter-subject communications facilitate the conscious assimilation of the notions in one subject matter by adopting similar-meaning ideas from other subject matters. They also heighten interest in the content of education, provoke student thought, contribute to the restructuring of the logical structure, teaching modes, and teaching techniques.

With inter-subject communications, the Developmental Didactic Block takes the study topic out of a discrete subject matter, integrating it into a distributed network of educational content. Thus, the nature of the learning process changes tremendously: the subject-related topic is studied just as well in the contexts of other subject matter contents. Moreover, transferring knowledge from one subject domain to another develops competency-based thinking as the ability to see the-universal-in-the-singular and analyze the singular from a universal standpoint, to make use of knowledge and skills for tackling interdisciplinary practice-oriented tasks.

A specific function of inter-subject communications in digital education is an integral (multidisciplinary) modeling of real-world objects, processes, and phenomena. This function comes into practice out of the DILM module. Inter-subject communications, shaped by digital technology as stand-alone inter-subject modules, are free to move in the digital space of educational content. They become part of local educational networks. They model various natural objects, social structures and processes, cultural events, pieces of art, and practices by applying multidisciplinary knowledge. In local networks for content, the learners develop their skills to work with the cross-curricular linkages by employing previously acquired subject knowledge.

The Developmental Didactic Block, as well as the Reproductive one, contains auditory accompaniment and multimedia. With the learners self-mastering the contents of the two blocks out of school, the availability of auditory accompaniment and multimedia in both of them opens the door to a new methodical technique, exploiting artistic modes for presenting learning material.The purpose of such methodical work suggests giving expressive and semantic integrity to the content of the study topic. Digital content shall be submitted not only scientifically, systematically, and be accessible but also artistically, so that man, studying this content, enhances not only personal thinking but also receives a profound aesthetic pleasure. Such opportunities become viable only with digitization and modular integration of the learning material. In works of art, aesthetic experience dwells in their multi-layered semiotic structure (text, music, moving images, rhythmic change of paintings, etc.). Similarly, in a digital learning module, aesthetic perception of the content arises from presenting the study topic in various ways: verbal text, auditory accompaniment, multimedia, inter-subject communications.The DILM module can generally work as a work of art. Its content can exercise a great and robust aesthetic effect on the actor of education. The effective development of emotional intelligence occurs by enhancing man's rational thinking and human feelings.

6.4 Resulting Didactic Block

With three consecutive didactic blocks of the DILM module, a solution to the problem of paramount importance in the post-industrial and digital economy — enhancing student cognitive activity — can be achieved by pedagogical means. When moving from block to block, the student's mental activity heightens, rising to a higher creative level in the Resulting Block.

The first Reproductive Didactic Block ensures the assimilation of objective knowledge: the learner's memory stores and accumulates information. Here, the learners master algorithmic actions — skills — while working with information by solving subject-specific problems. In this didactic *block, reproductive skillsare* built, including the student's ability to understand, memorize, reproduce knowledge on the study topic, and apply it by example.

The second Developmental Didactic Block aims at shaping interpretative skills. This activity intersects with the learner's desire to derive meaning — a deeper view into and comprehension of the study topic, setting up communications between multidisciplinary knowledge items, between theory and practice, mastering the ways of applying knowledge. The system of inter-subject communications helps to enhance these abilities. Translations of the previously acquired notions into the languages of other subject matters and practices make for interpretation — adding new ideas to the phenomena of study and deriving meaning through clarification and explanation. Learners create relatively new information (new for them, but not yet for other people) that complements the learning material, expanding its meaning through the processes of relatively adequate translations (unlocking the potential of inter-subject communications). The modes of interpretive activity can differ: commentary (interpreting and presenting the meaning in a new dimension), generalization (changing mental attitudes toward meanings), conclusion (exposing the cause-and-effect linkage between the meaning of the studied occurrence/phenomenon/notion and other meanings), analogy (presenting the study content as a metaphor, vivid image, model), etc.Translations from one educational language into another actualize the learner's subjectivity against objective knowledge, foster personal intellectual growth, encourage a move from "know" to "understand" as an intention: "I can convey the meaning to others"; "I can offer a new interpretation in a different language"; "I believe that...", etc.The interpretive activity leads to discovering meaning and acquiring personal knowledge (relatively new information) that complements objective knowledge.

The third Resulting Didactic Block supports and shapes a student's creativity that suggests vital cognitive interests, a collective search for problem-solving, and creating new information. Learning activities within this didactic block rest on active teaching techniques: business game (game simulation of scientific, cultural, social, and other activities); the analysis of a specific situation -case-study (collective reflection on real problems that require expertise on the study topic for tackling them); brainstorming (producing new ideas, meanings, information that expands the content of the study topic); search, educational and research activities (identifying contradictions between knowledge and ignorance, defining the boundaries of personal expertise, formulating problems that, once being solved out, provide the increment of knowledge); project activities (managing the future with the acquired and mastered knowledge); addressing non-standard tasks (searching for new algorithms for mental operations with knowledge); etc.

Students' creative activities include characteristics of mental operations that are at the highest levels of the taxonomy of educational goals set by L. Anderson and D. Krathwhol: analysis (breaking down the whole into parts and describing how the parts relate to the whole), organization (making diagrams and charts showing the place of a phenomenon, a process in its environment), attribution (determining authenticity or falsity, identifying specific features), evaluation (expressing an opinion based on criteria and standards), verification and criticism (finding criteria, determining the best method of proof), creation (integrating parts into a new whole, introducing arguments to a new structure), generation (using multiple hypotheses to explain a phenomenon, a process, creating an alternative hypothesis based on criteria), planning (creating a multimedia presentation of the research, writing an article), production (creating a product of activity).[56]

The learner can self-study at the level of the first two didactic blocks with the necessary teacher's support (remotely) and other students' participation (through social media and social learning networks). Shaping student creative activity requires real-life communication in a study group in the educational facility *with the guidance of the instructor*. The learner can self-create only relatively new information. This is not enough to develop thinking and build readiness

[56] Anderson L.W., Krathwhol D.R., Airasia P.W. Taxonomy for learning, teaching and assessing: a revision of Bloom taxonomy of education. N.Y.: Person Education, 2003. 336 p.

for productive activities in a digital economy. In the economy and other forms of social activity, only the information that is significant to other people has its value. Assigning an objective value to the relatively new information created within the second didactic block is a specific pedagogical task to tackle by active learning modes through real-life interactions of the educational subjects.

Learners go to school, to their class, already being prepared. Everyone comes with their vision and understanding of the study topic. It is subjective knowledge, everyone has theirs. Since the study topic is the same and the topic-related systemic knowledge is objectively established, its content becomes an object for the collective creative learning activity, with personal knowledge being various tools for comprehending. Everyone makes an intellectual contribution to creating new information based on objective knowledge. Through collective thinking, pedagogically organized as active learning modes, personal knowledge is converted into knowledge received by all educational subjects — the teacher and learners. This new knowledge already has an objective (within a study group) social significance.

The third Resulting Block derived its name precisely because, within its boundaries, the learner creates an actual product — new information resulting from the learning activity. It has a value not only for the learner but also for others, and consequently, one could consider it as a good (benefit).The creation of new information is an objective and observable result of student brain building, simultaneously being instrumental for further intellectual growth.

The school, providing a real-life collective work environment, remains vital for giving objective meaning and assigning social value to the new information product created by the learner. There were times when the student would come to school to retell what was written in the textbook and demonstrate the ability to solve problems with ready answers. Those times are flying away for good. In a digital school, through real-life interaction, man must learn to accomplish an overarching social task — to create new socially significant information together with other people.

In organizational and methodological terms, the Resulting Block includes recommendations for teachers on practicing, in a classroom, active learning modes on a given topic. It also has an assessment system for evaluating student educational achievements integrated into the school-wide system to assess and monitor the quality of learning.

Chapter 7. Digital Learning Opportunities

7.1. Mixed Reality in Education

The term “Mixed Reality” (MR) means inter-reality. It is a blend of real (physical, material) and digital (virtual) worlds when events occurring in both synchronize with one another. The educational subject can work with an object in both physical and digital reality simultaneously or sequentially. The word “virtual” comes from lat. virtualis — conceivable. In the late 1950s, the English word “virtual” took on a new meaning, indicating the appearance of the virtual: “Something that does not physically exist but is created by software to appear real.”[57] Due to the surge of digital technology, virtual forms multiply and gain in importance under the fifth information revolution. Their relationships strengthen and reach the state of extraordinary reality, with the Internet as its technological basis. The physical and digital realities are blending. Mixed reality is opening up revolutionary new opportunities for human activity and shaping technology for the Fourth Industrial Revolution. The digital economy itself owes its existence to MR. It would be logical to assume that mixed reality also plays a pivotal role in digital education.

Although mixed reality came into being together with the emergence of computers and their networks, the very principle of mixing the virtual (conceivable) and the physical (material) lies at the heart of human activity. It had been implemented long before the advent of digital computing. Activity always has two characteristics: thought and practice. Thinking operates with sign systems (embodied in languages) by which it models existing and creates conceivable objects. Thought shapes the internal side

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[57] Online Etymology Dictionary. http://www.etymonline.com/index.php?term=virtual

of activity (virtual, sign/symbol-based). Practice (working with exisiting objects) shapes its external side. In a real-life activity, virtual (conceivable) objects and material things intermix. The events of virtual reality (thinking) synchronize with physical reality: first, a notion, an image, a model, an algorithm of activity comes into existence, then it is put into practice for refining the mode and method of thinking. This correlation of thought and practice occurs in the activity all the time. Digital technology does not create mixed reality but radically extends its boundary, bringing virtual reality beyond human thought.

The principle of blending the virtual and the real determines not only the overall structure of the activity but also the way of organizing the learning process. In learning, the virtual space is organized by signs and symbols and held as teaching texts. This space is "created by software," being nothing more than teaching techniques for subject matters. It provides room for student mental activity (reading, memorizing, understanding, applying). It represents the internal side of learning activity. The external side of learning activity is organized through live engagement with the teacher and other students in the classroom.Real-life learning events occur here: questions, answers, discussions, joint problem-solving, etc. They are time-synchronized with virtual forms of content: knowledge, notions, images, symbols, models, etc. Also, didactic principles and teaching techniques are designed to facilitate integrating the physical and digital worlds. Thus, the principle of visual aids and the connection between theory and practice help synchronize a given content item of the virtual (text) reality with similar objects of physical reality or their quasi-real models.The project method involves student mental work with knowledge (search, analysis, synthesis, etc.) further integrated and tested in conditions as close to reality as possible.

Although the notion of "Mixed Reality" in its modern meaning[58] appeared in the 1990s, and, in education, the technology of blended learning began to be widely used after the publication of "The Handbook of Blended Learning (HOBLe) " by Curtis J. Bonk and Charles R. Graham in 2006, the idea of blending the virtual (sign/symbol-based) and real worlds has always been of great importance in pedagogy. The best quality learning and development can be achieved in the unity of knowledge and activity, theory and practice, education and life. The methodically organized blending of the symbolic and the physical paves the way to the learning organized by activity models that always combine thinking and the practical object-based activity. However, even though the very idea of blended learning has always been desirable for pedagogy, prospects for its implementation in education have been and remain limited. There are three key reasons for this.

The reason for mass education not to be following the activity paradigm as the unity of thought (the virtual) and practice (the real) lies in the lack of integrality of its content. The first sign of reality is its continuity. Man perceives it as a whole in his mind and senses, comprehends the nature of links connecting different parts of reality, finds his place in it.Reality for him is self-valuable; one can live in it really and/or virtually.That is not true of education. Its content breaks down into a multitude of systematically unrelated academic subjects. The place of the student is formalized by an impersonal system of rules and regulations, and, as a rule, they fail to find any value or meaning in the educational content. The advent of digital technology does not address this challenge on its own accord. Thus, all known models of blended learning, alternating phases of e-learningand collaborative training

[58] Any reality can be considered an MR if it dwells between two "extreme points" - the physical, sheerly real, and the artificial, sheerly virtual, world. *(R. Milgram and A. F. Kishino. "*Taxonomy of Mixed Reality Visual Displays *IEICE Transactions on Information Systems, Vol E77-D, No.12 December 1994).*

(joint, "face-to-face," in a real-life environment), are carried out within discrete subject mattersand do not affect the integrality of the entire content of education. An educational reality filled with meaningful content does not exist. We can only talk about its scattered fragments within discrete subject matters.

The second reason is that reality is always concrete, consists of many objects that interact between themselves and change. The content of education is abstract since it consists of theoretical knowledge on discrete subject matters, which are often difficult to relate to real or virtual objects. The learning process suggests that students move from knowledge to knowledge. Objects therein are replaced by a simple and episodic visual presentation like a textbook picture, laboratory equipment, or dummy models used strictly within discrete subject matters.

One more reason lies in the limited opportunities for activity in the educational system. Man discovers reality, enters it, masters it, and manifests himself in it through activity. The activity, however, is always directed at a particular physical, cultural, or intellectual object. There is no objectless activity (A. N. Leontiev). Learners acquire ready-for-use scientific knowledge and consolidate it as skills — specific mental and practical actions. The lack of activities is being addressed through project-based and research-based teaching methods. Still, these alone do not change the general nature of education, which has been and remains transmissive and based on knowledge reproduction.

All these three factors disappear in a digital school. It provides an enabling environment for learning activities in a mixed reality that merges virtual (sign/symbol-based) and physical (social relations and object-based activities) worlds.

In a digital school, content is networked in the unity of subject matter and intersubjectivity, which ensures its integrality. Within the core curriculum, the content is coherent and differentiated by distinct areas of subject matter content.It is comprehensible and shapes a sign/symbol-based reality.This virtual reality makes sense; it enables activities that provide transitions into the reality of social relations, practices, and creativity.

In a digital school, the learning activities deal with real-world objects, reproducing them through digital content.It is organized on three levels.

The first (subject-based) level of educational content consists of knowledge, skills, and abilities. In a digital school, subject matters retain their structure, content, and teaching techniques. Also, the assimilation of systematic scientific knowledge and skill/ability shaping remains a critical pedagogical task.

The second level is cross-disciplinary. It provides an in-depth study of the content components of a single subject matter through the others. The systematic application of inter-subject communications reveals knowledge items in their semantic, essential dimensions. The cross-disciplinary[59] content emerges at the intersection of subject matter/inter-subject lines through through differently organized educational languages.

The decentralized network of content supports the first and second content levels in the unity of subject matter and intersubjectivity. The network ensures the integrality of content within the core curriculum.

The third level, trans-disciplinary, involves modeling holistic objects, processes, phenomenaof nature, and societal events through various subject matters. The trans-disciplinary[60] content emerges beyond the boundaries of subject matters but based on them. This level of content is supported by centralized (local) networks built on top of the decentralized network of educational content. Every centralized network recreates real or foreseeable objects on an interdisciplinary basis.

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59 The prefix "cross" means: intersecting, criss-cross, opposite.

60 The prefix "trans" means: across, beyond, on the other side.

The two-tier network of digital education content shapes mixed reality. As part (the first level) of it, the distributed network organizes virtual (sign/symbol-based) reality consisting of knowledge items. Local networks (the second level) recreate objects, processes, and phenomena that exist or are conceivable in physical reality. These are still models of existing objects but those that students recreate themselves with the teacher's support if required.And having learned to work with the models consisting of multidisciplinary knowledge, they can easily cross the border separating a real object from its full-size dynamic 3D model.A valuable feature of the learning activity is that 3D modeling is carried out in digital reality.It is based on powerful hardware and is a multidimensional space for educational subjects to interact with objects and one another, fully or partially immersing into it and experiencing a sense of the reality of what is happening. Digital interactive reality recreates material objects, processes, and events related to other phenomena of nature, social and cultural events, and forms of thought, making the border between the virtual and real worlds completely transparent and inter-penetrative.

In a digital school, activity, which is nothing less than conscious and productive activity directed toward a given object, is pedagogically organized within each study topic. In the first two blocks of the DILM module, the student independently acquires knowledge and builds skills in interdisciplinary contexts. E-learning occurs in a virtual reality consisting of teaching texts. Learning within the Resulting Block of the DILM module already takes place in the reality of the student's social interaction with the teacher and other students in the school classroom. Entering a classroom, the student moves from the virtual to the real educational space. The nature of his learning activity radically changes. If, out of school, he self-masters knowledge, then in a study group under the teacher's guidance, he actively participates in creating new information. Teamwork shapes creative experiences and an emotional, value-based attitude toward the subject matter under study. The Resulting Block employs active learning modes. New information created by students in collaborative learning activities refers not to scientific knowledge but real objects, processes, phenomena of nature, and social events.The product of their learning activity — new information — connects scientific knowledge on the study topic with the corresponding real-world object and its learning model.

Thus, the digital school facilitates learning activities in mixed reality.It has all the necessary signs of reality: the unity of content, objects (real and virtual) alongside conditions for interacting with them, including the possibility to perform productive object-based activities.Mixed reality consists of the sign/symbol-based reality, organized through the unity of subject matter and intersubjectivity, and the reality of socio-pedagogical interactions, joint learning activities, as well as objects and their 3D models, which students master through active learning modes.

Digital education in mixed reality not only opens up new learning opportunities: the integrality of content in the unity of all four components, modeling real objects and their systemic relationships, readying for productive information activity, the systematic use of active learning modes, etc. It is a prerequisite for addressing the burning issues of present-day childhood caused by universal informatization. One of those issues is virtual autism. M. Zamfir defines it as a decrease in live communication skills under the influence of information technology. The symptoms of virtual and real autism are nearly identical: the lack of social reciprocity, eye contact, a sharp decrease in language and mental development, etc. The reason is not only and not so much that the child spends a lot of time in front of the computer or smartphone screen. It's much deeper. The problem is that no one teaches the child to work with digital information efficiently and responsibly, no one readies them to freely and consciously move from the virtual to the physical world, from the sign/symbol-based environment back to social interaction. Moreover, the school works so that it fosters the growth of virtual autism. Throughout all years, the school fashions a passive consumer of information. The traditional reproductive learning aims at transmitting ready-for-use knowledge and consolidating it as simple standard skills. The student absorbs torrents of multidisciplinary teaching information, items not related to each other and often out of touch with reality. The school, shaping the passive and uncritical perception of information, mothers virtual autism in children and adults if they spend too much time in a digital environment. Flows of information emerging from the Internet are emotionally charged; they possess artistic power and are available as games. They can hold man's attention for a long time. Yet man's attitude to information flow and the educational content is the same — passive and consumer-like, not related to creativity, activity, making, and real life. The student can do nothing with teaching information but assimilating it with no relation to activity, thought, and life. Following the pattern learned at school, they feed their minds with information emerging from the Internet, leaving no room for reflection, thought, action, creativity, and engagement with people to tackle socially significant problems. The student fails to move smoothly from the content of subject-based learning to real life and back. Being unable to self-work with diverse information related to the physical world and real life, the student, being immersed in the Internet, breaks away from social and physical reality and often drowns in digital information torrents.

It is impossible to ban the Internet and stop further development of digital technology. It is necessary to shape the human ability to work efficiently with digital information from an early age. Therefore, first of all, it is necessary to change the system of mass education. In a digital school, both virtual and physical realities are integrated into a single continuum of Nature, consciousness, and life through human activity directed at creating, together with other people, new information — new orders of symbols and/or material elements of social significance.

7.2. New Quality of Pedagogical Relations

In digital education, not only content, modes, and technologies are changing, but the key part of the school's workings — pedagogical relations — are being restructured. Pedagogical relations are the type of social relations. They are exercised to shape man's readiness for a particular kind of activity: intellectual, social, cultural, professional, or other. Participants in pedagogical relations are teachers, students, and their parents, heads of educational facilities and educational management bodies, politicians, public and religious figures, scientists, business people who are somehow involved in the implementation of educational programs, as well as other individual and collective actors whose area of interest is related to education. People open up pedagogical relations if they pursue personal (personal-and professional) growth or contribute to other people's development through learning, self-learning, and enlightenment.

Pedagogical relations are exercised through teaching/learning processes. In the structure of pedagogical relations, one can distinguish the core (center) and the periphery. The nuclear structural arrangement centers on teacher-student relationships. Only they, in real terms, pursue learning objectives and increase or decrease the quality of learning processes and outcomes. All the other actors, in one way or another, influence the learning process and the activities of its key participants. They do not directly play part in the process, remaining on the periphery of pedagogical relations. However, this fact does not reduce their socio-pedagogical significance. The peripheral pedagogical relations focus on integrating education and the State, economic, ethnic, and other social systems.

These relations are adaptive and flexibly respond to changes in the learning environment. Parents directly influence their children's learning process, taking into account various factors changing rapidly. Politicians set new challenges for schooling, depending on the socioeconomic situation in the country and the world. Scientists develop and implement innovative educational solutions. Driven by their interests, various actors of peripheral pedagogical relations run the learning environment in line with public life and its development potential.

Nuclear-type pedagogical relations remain extremely stable throughout history. Their essence is irrespective of the socio-economic environment or even teaching techniques and modes of learning. Neither scientific theories, nor the most progressive laws and educational standards, nor various types of education-focused development programs directly impact the quality of pedagogical relations. Arithmetic and Ohm's law are still learned in the same way as they were in the past centuries. And if the educational content and its overall organizational structure do not change, then the nuclear-like pedagogical relations also remain unchanged.

Thedisciplinary approach of nuclear-type pedagogical relations has dominated in learning up to now. It is critical for reproductive learning with the assimilation of ready-for-use systemic subject knowledge. The teacher is a bearer of knowledge. In the learning process, the teacher, who masters the entire educational content, delivers knowledge to the student. Symbolically, one can describe this process as "pouring" knowledge from a "full vessel" (the teacher) into an "empty vessel" (the student - the person without the necessary knowledge). In this case, the full vessel should stand higher than the empty one. In traditional schooling, the teacher is superior to the student in knowledge, experience, age, social status, and education; he knows more and is professionally prepared to impart his knowledge.

Classical teaching inevitably forms a pedagogical relationship based on strict discipline, subordination, the teacher's superiority over the student, often turning into authoritarianism. The reason is simple — reproductive learning. The student learns by assimilating and reproducing ready-for-use knowledge. When a socially-minded man is bound to be engaged in work that does not require productive intellectual activity, boredom is born, sense disappears, and the interest in learning is lost. To maintain such workrequires discipline[61] — organized coercion, an externally established order of behavior that requires unchallengedcompliance. With the disciplinary approach, the teacher demands, the student complies with the command. Typically, answers to questions like: "Why should I study?» are outside the context of learning: to get a good grade, to avoid punishment, to enter college or university, to grow into a cultivated man, to become successful, etc. The poignant and undying interest in educational content and knowledge is not encouraged pedagogically and may only arise when driven by the learner's particular personality traits and time preferences. Discipline replaces the lack of productive intellectual activity of both the student and the teacher. Coercion is necessary when the learning process is bound to transmitting and assimilating ready-for-use knowledge.

The disciplinary pedagogical approach essentially remained unchanged for thousands of years. Gaping chasms appeared in the late 20th century, and they were quickly deepening as the Internet and its information- and educational resources were developing. The teacher-student relationship has changed dramatically in recent decades.

The nuclear-type pedagogical relations always have a hierarchical structure regardless of the historical epoch and the logical arrangement of educational content. The teacher-student relationship

[61] Lat. disciplina, from discere - to teach

is perhaps the only disparity that has great cultural and social significance. The possibility for teaching opens up if one has intangible riches that other people need and is willing to transmit them. The possibility for learning lies in man's ability to accept these inner riches from his teacher through systematic work and in the process of personal growth.

Pedagogical hierarchy is ensured by the formal and informal authority of the teacher. He holds a teaching position and is professionally trained for it; his qualification is widely recognized. He has sufficient teaching experience, and his personal culture commands other people's respect.Formal authority is largely made up of this.The teacher's informal authority rests upon the fact that he has some life experience, cultural level, way of thinking, and activity, which he is ready to convey to his students, whose personal growth is unproductive or even hardly feasible without his instructions.Understanding the necessity of what the teacher gives underlies a sincere, truly respectful student attitude toward the teacher.

Long before the advent of the computer, the Internet, and the digitized content of culture and education, when books were not cheap, and knowledge opened the door for career advancement and material well-being, when social changes accumulated for a long time, the informal teacher's authority was ensured by three objective factors: a wealth of rational knowledge, methodical ethics, and considerable life experience. The Internet, remote e-learning, and personal computers create an environment with the informal teacher's authority to decline readily and steadily.

From the onset of human civilization throughout the late 20th century, the school was the only place where one could obtain both the necessary systematic knowledge and social recognition in the form of a certificate or other document certifying that knowledge was acquired. The bearer, the owner of this knowledge was a teacher. In the information society, the teacher loses the monopoly on knowledge. Knowledge is open and integrated into all social relationships. Computer networks perform an automatic search for, selection, and delivery of any information. Limitations in making use of information may occur solely due to the lack of capabilities of a particular person: for example, insufficient knowledge of a foreign language, lack of free time, lack of interest, or the undeveloped ability to perform the solo cognitive activity. Theoretically, there are no restrictions on receiving information and education. Various educational programs are available on the Internet, and there are many e-schools with full packages of learning services. What can the teacher give the student that the latter cannot get on the Internet under such circumstances?

Another overarching pedagogical task that traditionally supports the "teacher-student" hierarchy is sharing life experience. Knowing life, possessing both work ethics and vocational qualification, the teacher can help the child with socialization and decision-making in difficult life situations. This was the case until the acceleration of social progress reached a critical point that completely changed the balance between public and private life. In earlier times, human life was naturally changing against the background of relatively stable social relations. Social change was slow, and its duration far exceeded the life expectancy of an individual. Today, the world is different. In the face of rapid social and technological changes, older people can no longer directly pass on their experiences to the younger generation. There is no life they knew anymore and will not be. The young adapt to the new social environment faster and better, and the experience of the older adults is often unclaimed. The teacher belongs to the older generation, for whom adaptation to the new society is usually not easy. Often, educators themselves need social, psychological, and instructional support for embracing new working experiences in a qualitatively changing social environment.

The processes of informatization of education and accelerated social development devalue pedagogical work in its traditional form and significantly reduce the informal authority of the teacher.He has virtuallyceased to be a source of knowledge and experience for the student.The teacher continues to do what he has always done.But what he can give the student today, the student can get without direct communication with the teacher. The teacher is no longer the exclusive bearer of objective and personal knowledge instrumental in successful socialization. The hierarchy of pedagogical relationships is preserved mainly due to traditional and largely formal social statuses. Everyone suffers from the formalization of these relations. A student who fails to find his teacher ceases to be a student, and his opportunities for learning, development, and socialization are severely limited.A school that does not transmit vital, social, cultural experiences becomes a factor in disorganizing society due to the breakdown of inter-generational ties.

Digital education has the potential to restore the teacher's informal authority and the full-fledged hierarchy of pedagogical relations. The new teaching/learning process organized on a modular-integrative basis that significantly changes the nature of teacher-student pedagogical interaction can serve this purpose well.

Digital education transmits objective knowledge. The transmission occurs within the Reproductive Block of the DILM module. Digital pedagogical technologies allow the student to master the material on a new topic independently.He can get his teacher's consultation remotely if need be. And yet, even such assistance is organized by him, being his active dialog-based independent work: he addresses his teacher, asks a question, formulates a problem, defines the limits of his knowledge, "understanding his own ignorance." Knowledge control is carried out automatically, with no face-to-face interaction with the teacher.

The Developmental Block of the DILM module allows the learner to work efficiently with learning material and create relatively new information. However, for turning it into really new information, it is necessary to assign an objective value to it. Only other people can give this objective value, provided that this information is engaging, relevant, and valuable for them and their information activities. The student can tackle this problem in a school environment under the instructor's guidance, in a study group pursuing a common goal of both personal and social significance — creating objectively new, socially significant information.

At the final stage of mastering the study topic within the Resulting Block of the DILM module, sound pedagogical relations are built up. Each student comes to school with his own understanding of the new topic — with the new information he has created based on the previously mastered material, using inter-subject communications as tools for intellectual work. Learning activities at school imply addressing complex challenges jointly, conducting training research, developing learning projects. These activities shape themselves through active learning modes and ensure that scientific knowledge is applied and new information is created. The learners jointly perform the workings of the mind under the instructor's guidance, and everyone contributes the relatively new information that they previously created on their own. In such activities, guided by the teacher, a relatively new piece of knowledge produced by each student is integrated with the information created by other students. It is then applied to tackle common problems and turns from relatively new into real new knowledge, becoming understandable and engaging for other people.The new information created by the educational subjects acquires social value and objective significance.

In a digital school, the real teacher's activity focuses on enhancing student thinking through active teaching modes. They facilitate the processes of collective creation of new information based on the assimilated multidisciplinary knowledge items. Under such circumstances, the teacher becomes vital to the student again. The educator professionally helps the student become a productive actor of digital socioeconomic relations, supporting the development of his independent creative thinking. Everyone can find knowledge on the Internet. The availability of e-learning resources and distance learning helps independently assimilate information required. However, this does not provide an intensive development of human intelligence. To think, one must produce information that matters to others. The teacher guiding a study group becomes essential to the process. In no place other than school will the child receive social recognition of his productive information work. Digital education brings back the teacher's informal authority. The teacher is no longer only a bearer of knowledge but also the owner of the processes that led in the past and lead in the present to acquiring new knowledge.

7.3. Advancing the Economic Status of Teaching

The nature of the benefits produced in a unit of time determines the actual cost of labor. Under traditional schooling in an industrial and agrarian society, the teacher managed the processes of acquiring knowledge and building skills.He was the owner of this process, and he himself carried it out. The acquisition of knowledge is an undeniable good for man. Knowledge is light, power, and new opportunities. Knowledge-giving labor was worth a lot in the olden times.

In the information society, the economic value of teaching is changing. Systemic knowledge is no longer concentrated only in books, and the teacher and the school are no longer the sole owners of the knowledge-delivery process. The variety of distance learning programs provide the knowledge required at a give-away price or even free of charge and offer accessibility, easiness, and consistency of learning in handy modes. If replaceable by a distance learning program, ateacher's work really costs the same as access to that program; the rest of his salary is a hidden social benefit. The information society markedly reduces the cost of traditional teacher work. This objective economic process increases psycho-emotional pressure, causes professional deformations, with the motivation for pedagogical work going down. This problem will turn into an unmanageable issue unless the learning process is changed.

With education going digital, the nature of the benefits created by pedagogical work is changing. Transmitting knowledge remains mattering but is no longer the overarching learning objective. Shaping student ability to perform productive activities, getting them ready to create new information employing objective systemic knowledge turns into a new learning goal.Qualitatively new levels, modes, and ways of thinking achieved through teacher-led learning processes are beneficial. No information machinery will teach a man to think deeply, productively, and innovatively and create new meanings. The teacher possesses and masterminds the development of thought and activity.

The cost of services for the continuous qualitative development of both thought and the ability for productive and creative information handling is objectively high. This kind of ability is vital for a man in the information society and digital economy. It is successively shaped from the primary school age. In a digital school, the teacher work creates high-priced social benefits — it shapes and continuously develops basic (universal) competencies demandedby the digital economy and guaranteeing successful personal socialization.

Digital education significantly increases the objective cost of teaching. And it also requires a much higher professional qualification of the teacher. For student brain-building and enhancing student ability to perform productive information activity, the teacher himself must be a subject of independent creative thinking and have extensive experience of responsible and fruitful activity in its various forms and conditions.

7.4. Digital School's Tenor

The school's tenor is the most common teaching mode that integrates information, communication, object-spatial, social, school-family, territorial-cultural, and other learning environments. It combines the open, pedagogically codified content of curricula and mentoring and the hidden content of relations between the participants in the teaching/learning process that is not entirely amenable to pedagogical planning. The school's tenor helps engage the learner in a complex world of values, traditions, sociocultural practices, encouraging them to acquire the necessary social experience. It represents a specific order of the vital functions entrenched in schooling through explicitly or implicitly existing norms and rules of conduct and relations. The activities that educational subjects perform, the overall organizational structure of learning, and the focus on achieving particular goals regulate the school's tenor. Digital education defines a special school's tenor. Let us consider some of its features.

Gradual Student Integration into Digital Reality of Education. The content of digital education is consistent with the traditional one. Similarly, the existing school's tenor in its best manifestations should be preserved in a digital school, first of all, at primary education level.

The first schooling years shape the necessary universal study skills: reading and writing, working with texts, mathematical skills, searching, evaluating, analyzing, synthesizing information, etc.As the students become ready, self-study activities are gradually expanding by further introducing a growing number of the DILM modules. The value of pedagogical relations in the primary education system is instrumental in preserving the traditional elementary school inside a digital one. The elementary school child is usually highly motivated to learn due to the attractiveness of their new social role as a student. The primary school still retains some mattering features of the child's family lifestyle: one teacher, regularly working with the children, symbolically replaces the parent, the possibility of individual pedagogic work, attention to each child consonant with parental care.

At the basic education level, the nature of school's tenor markedly changes. The modular-integrative content of subject matters allows the learners to acquire new knowledge out of school in easy-to-use operating modes. They come to class prepared, each with new information received by employing inter-subject communications and doing relatively adequate translations. In a digital school, classes become a kind of knowledge laboratory. Study groups turn into creative teams that jointly solve non-trivial complex tasks under the teacher's guidance and create a new information product, everyone making some exceptional, meaningful contribution. The school becomes a place of joint creative work for the educational subjects.

At the level of high-school education, mixed reality becomes as extensive and elaborate as possible. It opens up opportunities to include students in solving feasible socioeconomic problems and their self-determination in the world of professions. Creative work is advancing, and the intensity of learning activities focused on real-world problems is notably increasing.

Study Group Organization. The digital school maintains relatively stable teachingstaff. With that, the student body's organization is no longer limited to the school class; it becomes open and considers individual learning needs and personal priorities in communication.The student has vast opportunities for network communication and can join existing or create new social groups, employ social media, and networked communities, which unite people motivated to achieve common goals and allow students of different ages to exchange information when facing learning challenges or personal problems.

For productive network communications, each DILM module provides a technical possibility for students to communicate online when studying a specific study topic. In acquiring new knowledge, students interact regardless of time and space, exchange views on different aspects of the topic, discuss difficulties in understanding a particular issue, and help each other to learn. Networked learning relationships, technically easy to organize in a digital school, fully implement the concept of peer learning, also known as the Belle Lancaster method. According to the report, the better-trained learners act as the teacher for the other group members, helping them acquire the knowledge they already possess.

Networked educational communities drastically expand the concept of a school grade and its real pedagogical boundaries. In a digital school, not only content but also social interactions are organized in mixed reality. The study group consists of a real school grade and virtual study groups. A school grade is a formal and steady-going small social group, a pedagogically managed team whose members pursue learning objectives in constant and close interaction. The complementary networked communities operate in virtual space, and the learner manages them quite easily. The DILM modules synchronize ILC (information, learning, communication) activities between the two. This allows the learning process to follow the model of social relations: the learner builds up social connections and pulls social strings for problem-solving. He presents his idea consolidated with his virtual classmates' views in the classroom and includes various helpful social relations in the training process.

Online Teacher Communities. Online professional communications grow stronger in the digital school. Online teacher communities and education administrators become more popular due to the pedagogical work changing its nature. A significant strengthening of the creative component in learning/teaching, systematic work with students on creating new socially significant information invariably poses new challenges to the teacher. Online teacher communities that quickly tackle similar tasks become necessary in everyday work. With single-tier ("profile") networks, they can exchange information on specific job-related problems, start creative groups to address particular issues promptly, while regularly shaping their skills and saving time and effort to search for the information needed. The single-tier networks of various teacher communities can accumulate vast volumes of relevant information on various job-related issues.

Integrating Basic and Extended Education. Networked content facilitates the process of integrating basic and extended education. There are two main ways of achieving such integration in the digital learning space.

The first involves digitizing extended education programs and organizing them on a modular basis.With this approach, modules of extended education can be integrated into the DILM as interdisciplinary modules. In turn, digital modules of basic education can be integrated into continuing education programs. Today, a national network of technology parks for children (quantoriums) is being built in Russia. [62] The research programs available in those parks, modeling, constructing, working with large databases, and other activities may become a complementary driving force for the basic learning process reinvigoration. Also, mastering modern technologies in quantoriums will be much more productive if they are digitally synchronized with acquiring systemic scientific knowledge at school.

The second way of integration involves creating a unified system for recording the learning achievements of students. Brain-building activities must be considered as full-fledged modes of learning. Sports, musical or artistic studies, training research, social work, and other forms of extended education

[62] https://www.roskvantorium.ru/faq/

and socialization must be recognized on an equal footing with the school studies. In a single digital space of the city, district, or region, it is technically feasible to set up a distributed education network with a unified system for recording learning achievements.

Individualizing the Learning Process. The digital modular-based integrative architecture brings the content and the modes of learning in line with each learner's needs and capabilities. The digital education content in each study topic is variable. The DILM module with built-in elements of artificial intelligence provides the necessary transitions from one level of complexity to another when studying a particular topic, depending on the student's readiness level and interests; the module can tune itself to his individual cognitive needs.The distributed network of the content of basic and extended education has great potential for building individual learning routes. In the digital educational space, the school strengthens its functioning as a center of socialization for the learners. Integrating both digital basic and extended education does the groundwork for social and cultural practices, vocational tests, and the acquisition of experience in productive social activities. The learner may need a tutor to implement these opportunities.The tutor provides professional-pedagogical support for the processes of individualization of learning and socialization of students. The subject teacher specializes in the objectives of developmental learning. The tutor, on the other hand, is supposed to help students organize their own program of basic and extended education, as well as a personal socialization program.

Personalizing the Spatial and Material Environment. The space in the traditional school looked like that of a factory:a simple linear geometry of the rooms, typified objects inside, the lack of personal space, etc.Such a learning environment is not conducive to achieving the goals of digital education. However, refurbishing all school buildings and turning them into palaces of creativity and innovative modern offices is physically unworkable. And yet, there is a solution. It stems from the special architecture of digital education. The modular-based integrative arrangement of educational content opens the door for the learners to master new material at the reproductive and developmental levels independently and out of school. Also, training sessions in physical and sports, music, artistic and technical creativity, and social work can be held in facilities for extended education, museums, theaters, public, and other organizations that deliver educational programs. The time the learners spend at school shrinks. Reducing school hours frees up space. A flexible core curriculum helps as well. Learners, together with teachers, choose a convenient time to have classes. The availability of free time and space makes for improving the school's spatial and material environmentin tune with the objectives of open developmental learning.The digital school's space becomes available, interiors — mobile, and premises can accommodate diverse activities: learning active modes, games, negotiations, relaxation, etc.

Combining Education with Productive Labor. The digital economic activity aimed at creating new information — new orders made of symbolic and physical elements — opens up this opportunity. Digital education can be seen as a special type of digital economic relations because the teacher, the student, and the study group create socially significant information. Working with objective scientific knowledge, they create new digital objects — milestone products of the digital economy.

The digital economy restores the rights of productive child labor[63] but as an intellectual, creative, developing, and free one.

[63] Child productive labor means attracting children to work on a regular basis. It was popularly deployed in factories in the industrialized countries of Europe and America in the 19th century. With the recognition of the rights of the child, it became a form of exploitation and was prohibited (article 32, The UN Convention on the Rights of the Child). Today, it continues to show-business and creative activities: stage, cinema, theater.

The students not only gain knowledge and consciously work with it. Indeed, each of them creates new information valuable for them and other people, first of all, teachers, students, and other actors of educational relations. Productive, creative child labor aims to create intellectual, artistic, and other information products. It is one of the most promising areas of digital economic activity due to the peculiarities of the child's thinking. Traditional psychology viewed it, as against adult's thinking, as primitive, insufficiently developed. The founder of the alternative approach is Jean Piaget. He defines a child's thinking as qualitatively different from that of an adult and particularly valuable because it implements other strategies to comprehend the world around and finds other ways and forms for information handling. Children, teenagers, and young men think differently than adults. While mastering scientific knowledge, they can create new information objects beyond an adult's depth. Each new generation, in a special way, recodes the cultural heritage received from the older generation. The problem is known as the "father-child conflict". In the information society with its high sociocultural dynamics, this conflict takes on a positive value. It becomes one of the drivers of the digital economy: each new generation, while assimilating, perceives culture and thinks the world differently from the previous generations, which opens up additional opportunities for information activities. As soon as they have acquired basic scientific knowledge and mastered digital technologies, the high school students become able to create new information objects. Digital schools provide this kind of training. Students are free to enter economic relationships through networks of economic activities that enable an individual anywhere in the world to participate in creating benefits through digital technology.Digital free child productive labor is a continuation and development of the information activity that takes place at school. It can ensure the student's efficient socialization, enhance his positive self-attitude, and strengthen the connection of learning with real-life and economic practices.

In the information society, teaching, learning, and networked pedagogical relations acquire an objective economic value. The high school students are ready to start solo activities on creating new, socially significant information objects. Networked educational relations become a vital component of economic networks. They accumulate knowledge, support continuous circulation and creation of information, build knowledge capital — a key asset of modern business. The teacher's work takes on special importance. In a digital school, he creates a boon of the highest value for a person entering independent life - the readiness for productive activity and self-realization in the digital economic reality.

Part III. Managing Basic Education Development in the Digital Economy

Chapter 8. Public-Private Partnerships in Digital Education

8.1. Resources for Setting up a Digital School

In terms of the quality of pedagogical relationships, basic content, the nature of actors' motivation for teaching and learning, and the principal modes of teaching, traditional schooling has not changed for hundreds of years.Created in the Industrial Age for shaping a skilled workforce and readying for non-creative information work, today's school can neither enhance human creativity and readiness to create new, socially significant information nor ensure the accumulation and implementation of human capital — the leading resource of the digital economy.

The system school building code continues to reproduce the modes of thinking, activity, and forms of relations inherited from the industrial society. However, nothing can resist a rapidly evolving new-type economy. The actors interested in developing the digital economy are ready to provide all necessary resources for finding immediate solutions to problems hindering the development of new socioeconomic relations.

Making basic education go digital is a complex and complicated social problem. Developing new content for basic education, refining the modes, methods, and techniques of teaching, humanizing the system of pedagogical relations, and bigging up the teachers' social and economic status — all this is yet to be done. The most challenging socio-pedagogical tasks must be accomplished under the rapidly evolving digital economy. Little time is allotted to meet the challenge because the digital school itself plays a pivotal role in the new-type economy.

Creating a digital school requires, in the first place, new pedagogical thinking. However, the real opportunities to set it up dwell in politics and economics. This is where the main resources for the education reform are concentrated. The search, attraction, concentration, and rational use of resources are the major issues in managing digital education development. It requires four types of resources: political, financial, technological, and scientific. Traditionally, the State manages all resources for the support and development of basic education. However, full-functioning digital education requires a powerful computing platform — a critical technological resource for going digital. Creating and sustainably developing the platform is a new and challenging task. Addressing this task leads to reconsidering both the nature of the resources themselves and their controllability.

The budget allocated to set up a digital school should ensurethe digital competence of the project developers, creative team building, introduction of innovative solutions, the legal and regulatory framework for educational development, etc. As the matter stands, only public-private partnerships can tackle the task of shaping new content for basic education and fitting it with digital technologies.

8.2. Business and Digital School

Traditional forms of business participation in education are fee-paying educational services, the development and sale of textbooks, teaching materials, and educational equipment. Before the information age, small and medium-sized businesses had worked in education. There were no hard factors for large businesses for a number of reasons. The content of education, its modes, and the major techniques were extremely conservative. The school science programs remained unchanged for decades. The programs and content of liberal arts education were changing, although only slightly, along with changes in the state system. The scientific and pedagogical community continued to live its "closed" intellectual life. The quality of the budget and commercial learning services, teaching materials varied, remaining within the same educational opportunities. Under these conditions, developing and implementing radically new educational products for the market of educational services and technologies was extremely difficult. Injection of capital in investment educational projects had a long payback period, and the projects themselves were not appealing for large businesses.

The prospect of setting up a digital school opens up new opportunities. The social status of education is changing: in a digital format, it is becoming a branch of the digital economy. Investing big bucks in setting up a digital school is an investment in the digital economy, in its most promising area — networked socioeconomic relations. Digital education goes online. It integrates, in a pedagogically sound way, the proper educational networks (networks of educational content), social networks (broad and multi-level interaction of all participants in educational relations), and economic activity networks (digital education, as well as the digital economy, aims to create new, socially significant information in its broad sense). The major driver for the business is the relatively short payback period for investments in creating a digital school. It is in the best interest of all political and economic actors that its formation occurring as quickly as possible.

The optimal financing of the digital school project implies pooling the State and the business resources in the form of public-private partnerships (PPP). For the most part, the business handles the financing for the project and controls the expenditure of its funds allocated for scientific and innovative developments. Commercial financing allows for the reliable and straightforward orchestration for timely and sufficient resourcing, in-process control of both innovation processes and their outcomes.

For real participation in digital educational relationships, the business needs tangible assets — its own resources of tangible and monetized nature. A computing platform for teaching/learning may become the main asset. The business organization owns the platform, and a public-private partnership agreement defines the terms and conditions of its use. It is also the technical basis for digital basic education.

The content of digital education is coherent, with each component connected to all others. The entire content is organized as a network of Digital Integrative Learning Modules (DILM). They must be stored on the Internet, accumulated, updated, systematized, and delivered to a personal electronic device at the educational subject's request. This requires automatic systems for searching, selecting, and delivering the requested modules, supporting interactive "communication" between the learner/teacher and the contents of the modules. Technical requirements are becoming more and more complicated due to the evolving nature of e-learning, calling for the educational subjects to create new information integrable into the core educational content. Networked content is a rather complex self-developing content that operates by the rules of artificial intelligence. It requires an equally complex IT software that is constantly evolving.

The computing platform for teaching/learning is a software- and hardware complex that provides a basic set of services required for pursuing pedagogical objectives in digital education. Broadly speaking, the platform represents a technically structured environment for conducting the core teaching/learning processes. Its lower level is shaped by the hardware architecture — a lot of servers, application software. The operating system is built on top of the hardware architecture. It provides the overall organizational structure for running the application programs. A higher-order organization of the education platform is cross-platform software. It allows the entire computing education platform to function in a stable way under different operating systems when changing programs, switching to other hardware platforms. The goal of developing cross-platform software is to maintain the stable operation of the platform as a whole while improving its components. The top organizational- and technological level of the education platform is the administrative management system. It incorporates a set of programs and organizations for the technical management of educational networks and their structures. This system provides for:

• devices monitoring and the working status of the cables;

• technological control of educational procedures;

• securing the core educational content according to the standards and requirements of the educational authorities;

• improving and upgrading the hardware and software for the education platform;

• monitoring other aspects of the platform functioning.

The computing platform technically ensures the operation of the entire system of digital education. With no computing platform available, it is impossible to create either coherent educational content or the integrative-modular structure of the content, nor regularly exploit inter-subject communications. Without it, digital learning modules cannot be developed, used, and evolved. The integrality of the educational content remains unattainable, together with personal results and meta-disciplinary outcomes.

Creating a computing platform for teaching/learning is an expensive project. Maintaining its non-idle status and continuous evolvement is no small engineering challenge. Only big multi-disciplined teams of experts in computer technology with motivation for a strong economic performance and creative potential could ensure the platform running and steadily developing. This is one reason why the best legal form for setting up a digital school is a public-private partnership.

The public-private partnership focuses on creating the computing platform for teaching/learning, providing technical support, software upgrades, and technological development. These tasks are the responsibility of the business organization. In return, it gains the right to take full commercial advantage of educational networks and other social media integrated with them. As per the agreement, the business organization can direct part of the profit from these activities for developing educational content, improving its techniques and technology. The business organization interferes neither with educational content nor the realm of pedagogical relations. Its activities are aimed exclusively at ensuring the effective operation of the computer platform and entrepreneurship, the types of which are set out in the public-private partnership agreement.

The main source of profit for the business organization can be the production, sale, and maintenance of specialized computer equipment, sets of educational equipment, various gadgets, software, other modern equipment, and technologies that are fully compatible with the content and technologies of digital education and necessary for pursuing learning objectives. The computing platform is a technological core that functions in artificial intelligence modes. Its extensive peripheral structures integrate the institutions of basic and extended education, culture and sports, public and professional organizations that implement education programs. All individual and collective actors of educational relations use compatible information technology that the business organization develops, supplies, maintains, and shapes.

Another item of its income is the advertising. Educational networking integrates other types of networks and represents convenient information services that, in one-window mode, provide a full range of educational services, vast opportunities for professional cooperation, interpersonal and inter-group communication, participation in creating and selling information, making purchases. In the future, educational networking may enter into serious competition with social media. The former provides a more convenient unified system of various inter-complementary digital social services. This will result in much advertising moving from social media into integrative social networks of continuing learning.

Digital education fundamentally expands the geographically-aware learning boundaries and, with that, the space of business relationships. The distance format enables distance learning anywhere in the world where translation technologies are in operation, and their quality is continuously growing. Educational services, equipment and technologies, software products, and the advertising can be sold worldwide.

What matters most for the business is that the computing platform for basic (mass) education is the first to be created.It will serve as a basis for working out innovative digital technological and pedagogical solutions.Further development of educational networks and platforms for vocational education will be already built upon the platform for basic education. Without losing its specific features, it has the potential to become a meta-platform for educational platforms of all levels and types of learning.

8.3. Public-Private Partnerships (PPP): the Cooperative Model

The State implements educational policy and sets requirements for the learning processes and learning outcomes. The business organization creates new information technologies, ensures the functioning of the computer platform, and co-finances the development of educational content and pedagogical technologies. IIt is not responsible for the content, quality, and learning outcomes unless the problems arising in these areas are related to information technology. Effective interaction between the state and the business requires one more social entity that provides comprehensive scientific and methodological support for the creation, functioning, and development of the digital school. Let us give it a conventional name: Institute of Digital Education (IDE).

The IDEdevelops and improves all curricula content on an integrative basis in the DILMformat and is responsible for the quality of the content, modes, and technologies of digital education. It regularly coordinates its own workings with the profile structures of the business organization for the coordinated development of educational content and the latest information technology.

The State, represented by a relevant ministry, finances its subordinate organization, the IDE, to the extent that it can keep a grip over its activities. Most of the necessary funds come directly from the business organization on the terms outlined in the public-private partnership agreement. For its part, the business organization monitors the funds' expenditure and determines the utilization efficiency.

In general, the interaction of government, business, and academia for the creation and continuous development of the digital school can be represented as follows.

Public-Private Partnerships

The State

Main mission :

- Setting requirments for educational outcomes;
- Assessing the quiality of digital education outcomes and processes;
- Making desicions in case of discrepancy between state requiremnets and educational outcomes;
- Co-financing the computing platform for digital education and IDE workings.

IDE

Main mission :

- Developing the DILM and technology for its pedagogical application;
- Enhancing the content and technology of education in line with state requirements and the latest information technology;
- Advancing teacher training for working with the digitals.

The Business

Main mission:

- Technical support for creating and operating the computing platform;
- Developing hardware and software for the computing platform;
- Performing business activity;
- Financing the IDE workings;
- Supervising the IDE extra-budgetary funds.

Public-Private Partnership (PPP) Model for Digital Education

Public-private partnerships are the optimal form of socio-economic relations needed to create a digital public school. The State ensures the functioning of education, and the budget allocated to science secures its existence and development. When it comes to the sprint implementation of scientific ideas and translation of theory into practice, as required by the rapidly evolving digital economy, the integration of science and business becomes crucial.

In digital education, the business occupies a niche for innovative developments and technical support for the computing platform. Business activities in education are motivated by profits derived from the operation of the educational network. And that makes the business a party that is really interested in the sustainabledevelopment of digital education. The faster its content, techniques, technologies are updated, the more intensively digital competencies develop; the faster the software and hardware change, the more advertising opportunities open up, and the quicker the business organization's profit grows. In turn, the higher the profit is, the more funds are directed to science and innovation; the faster education develops, the higher its efficiency and the quality of its outcomes becomes. The digital school is based on a sophisticated system of information technology that requires ongoing maintenance and development. Only a well-organized and motivated business structure is capable of sustaining the IT non-idle status. Public-Private Partnerships represent a self-organizing, sustainable system of innovative development in digital education. The State controls the system, which acts in the interests of the entire society.

The Public-Private Partnership (PPP) model is not the only option, but it is the only effective one. The State can take over all functions in developing digital education. And in this case, the digital school will be created and will work. But such actions pose risks to the national education and digital economy to lag in development in a globallycompetitive environment. The advanced and rapidly evolving digital technology becomes the technical foundation for a new- type learning. The digital school itself is an important component of the digital economy. Deciding to create a digital school and partly delegating responsibility to business, the State creates an enabling environment for the rapid development of education, economy, and human capital.

Chapter 9. Continuous Improvement in the Quality of Digital Education Content

9.1. Unity of Digital Curricula

The unity of curricula underlies the coherent content of digital education and the sustainability ofhigh-quality learning processes and outcomes.At each level of basic education, learning rests on unified curricula of academic subjects, timed by study topics.

In digital education, the curriculum, which defines the content of education, its study method, and the allocation of teaching time, is organized as a sequence of DILM modules. The modules are stored on the digital education platform and delivered to a personal computer on demand. The DILM structure is unified; however, the delivered content varies according to a learning environment, learning needs, and the learner's abilities. The digital module has virtually unlimited information capacity.

Digital content can be mastered at different levels of complexity: basic, advanced, in-depth, or other. Digital technologies with built-in artificial intelligence elements help recognize the student's level of readiness to perceive a particular topic and offer him the best ways to master it. Being arranged as a sequence of DILM modules, the curriculum facilitates studying each topic at the level of complexity that corresponds to the learner's capabilities and interests. There is no strict or permanent binding to the levels of complexity of the learning material. Everything depends on the learner's readiness to study a specific topic. Within each level of complexity, variations in the content within a given topic are possible.The DILM is "self-tuning" to different factors that determine the nature of a particular student's learning activities, ensuring maximum flexibility in mastering the curriculum.

In addition to flexible and soft transitions from one level of complexity of the training material to another, the DILM allows the learner to expand the content of the study topic. Specific inter-subject modules are built into the Developmental Didactic Block of each DILM module. They are related to each other, and the learner can independently search out for the additional cross-curricular content. In this way, he pushes the boundaries of the topic in line with his cognitive interests, regulates the nature of his interpretive mental activity for deeper penetration intothe essence of the objects of interest, and consciously and solidly acquires scientific knowledge.

The modular organization of curricula offers great opportunities for the development of inclusive education. Digital educational technologies assist children with special needs to self-administer the time, place, environment, pace of learning, determine the level of complexity for their study, vary the content and methods of its assimilation while moving from one topic to another, adequately interact with other learners, jointly pursuing learning objectives if need be.

The modular-integrative structure of digital content meets the educational needs of different study groups and each student individually. The digital school does not divide students into privileged and less privileged social groups. All of them study the same curriculum, and each one determines their level, pace, and depth of learning, the optimal volume of content.

The unity of curricula and synchronous training on study topics allow students, regardless of their training location, freely exchange teaching information and academic achievements and help one another pursue learning objectives. Also, they can choose a teacher. Through social learning networks, the student receives information about the specifics of the learning process in other schools. A unified record-keeping system for academic achievements, flexible school hours, the opportunity to acquire the content of a given topic out of school within the Reproductive and Developmental Blocks allow for searching and finding the right one among many a teacher from different schools.

Variability in learning becomes fully available in a digital school. It ensures that every learner's educational needs are met. Variability as the quality of traditional school characterizes its ability to create and provide students with options for different educational programs. Once the choice has been made, the learner can no longer choose or change anything. In a digital school, variability is the potential to present content to each student in real-time and such a way that it perfectly corresponds to individual learning activity style. It also ensures interactive communication between the learner and the content of education.

9.2. Education Content Development in the Pre-Digital Age

The unity of curricula is a necessary but not sufficient condition for ensuring consistently high quality of digital education. The second condition is the constant updating of its content.Let us consider to what extent the existing procedure for developing the content of education meets this requirement.

The main content of educationis presented in textbooks, or, more precisely, in methodical and training sets with a training toolkit, with a teacher resource book complementing the basic manual. A textbook is a book (text) containing a systematic (methodically proved) presentation of knowledge in a specific subject domain.

The content of education is and was updated in the past by developing and introducing new textbooks in line with the State's requirements and pedagogical science possibilities. Each textbook has an author (writing staff). Writing a textbook is not an easy process and requires special skills. A textbook author must have systematic scientific knowledge, a deep insight into the basics of a particular science, and see its relationships with other sciences, culture, technology, and social life. The textbook writer should be a good scientist and an excellent methodist: knowing is not enough; one needs to be capable of teaching and transmitting knowledge to others clearly and engagingly. Writing a textbook implies scientific, pedagogical, life, and personal maturity. In the information society, the traditional way to improve educational content becomes a pedagogical challenge.

In developing a new textbook for school, the author selects knowledge, determines the nature of learning objectives, and constructs a visual seriesof content in agreement with his world view and attitude.Through the textbook content, he conveys to learners the system of values and understanding of the world shaped by certain cultural and historical conditions. And even when the textbook is written, it is yet to be tested, polished, distributed. The teachers are yet to be trained to pursue a new program and take advantage of the latest methodical and training set. It takes years. As a result, students begin to study from the textbook, whose content is two or three generations behind the times.Throughout schooling, the acquired knowledge, modes of thinking, and world views (physical, mathematical, informational, biological, etc.) become even more obsolete. After graduation, a little of what they have learned remains relevant.This is not a problem when science, technology, and social relations remain relatively stable. But it becomes a problem in the age of a permanent scientific and technological revolution when reproductive learning, with the writing staff involved in shaping content, markedly depresses the opportunities for man and society.

Developing a new textbook is an expensive and time-consuming process.Its updated content will be new against the old textbook, but it is bound to be obsolete when the teacher picks up the "new" textbook.The chief shortcoming of the paper textbook is that it leaves no room for scientific and methodical correction of the content in the real-time learning process.

It cannot be improved evolutionarily, only replaced with a new one. In the paper-based environment, the correlation between educational content and fundamentals of modern science, technology, and dynamically developing forms of public consciousness is unfeasible. And no matter what "new" textbooks appear, their contents are bound to reproduce the outdated experiences of activity, thinking, and culture.

An attempt to alleviate, if not solve, the problem is the abandonment of a unified textbook system. After 1991, many publishing houses emerged in Russia, offering their new methodical and training sets. A large number of authors and writing staff were involved in shaping content. It became variable in the traditional vein. The teacher got the opportunity to choose from diverse content areas and methodical strategies, however, all leading to the same goal, i.e., achieving educational outcomes set by the Federal State Education Standards (FSES).

The variability of content, both organizationally and methodically, rested on diverse methodical and training sets. It was meant to empower the learners to choose a learning path corresponding to their abilities, cultural and educational needs and provide the ultimate possible individualization of learning. All the programs and textbooks approved by the Ministry of Education provided the required minimum of knowledge.Their signature features were shown in presenting learning material, organizing learning activities, presenting additional information, and selecting teaching/learning techniques. Content-related and methodical variations were necessary for individualizing learning. Each elective course was designed for a certain mindset, particular modes of working with learning information, which is individual for each learner.Different programs required students to have different initial knowledge and skills, special modes of thinking. Therefore, authors often introduced a special section in their electives, revealing the rules to master the learning material successfully. Each elective course was designed for a targeted group of learners with similar psychological makeup, forms, and types of thinking.

However, implementing this progressive pedagogical approach in a paper-based information environment appeared quite problematic. An elective course works well if the entire school grade consists of students whose mindsets match its methodical nature. Though, forming a grade from children with similar psychological types is next to unfeasible. Moreover, the study group reflects society, and each child must acquire knowledge and learn to communicate and work with different people. In the realities of school life, the grade always consists of children with different learning abilities and needs. And if they are taught by a special program designed for a certain mindset, then all those who do not possess it are in a quandary — this program is not for them. Until 1991, there were uniform curricula for all subjects. They were standardized and suitable for everyone due to their uniformity. A single textbook was equally acceptable for learners with different psychological makeup. The variability of curricula in the absence of real opportunities to change the existing administrative order of filling the class can only worsen learning conditions and, in general, reduces the quality of learning outcomes.It is virtually impossible to fit an entire school group into one specialized curriculum.The very idea of elective education is correct: students should study according to the curriculum that suits their abilities and needs.However, there should be a different way of putting the idea into practice. It is not the school grade that should correspond to the curriculum and the content of the textbook. On the contrary, the curriculum-based learning material should vary according to the individual characteristics of each student in the same class.

9.3. Modern Approaches to Quality Management

With their contents and teaching modes constantly updating, the formal unity of curricula programs is a crucial backbone of the quality management system for digital education.The integrative-modular structure of the content and its availability on the digital platform ensures the unity of digital curricula. How could their content be constantly improved? To answer this question, we should consider the existing quality management systemsfor economic activities and their evolution. The economy and education are deeply connected. Economic approaches to quality have defined and still affect the generic approach to quality in learning. The Industrial Age created traditional schooling. It generally shaped the content and modes of the learning process, the mode of thinking, the nature of pedagogical relations, and the quality management system for education.

The prerequisite for the traditional approach to quality emerged with the appearance of craft labor and commodity exchange. The essence of this approach is simple — the selection of quality products. Artisans produced goods, and buyers chose those that they rated as high-quality. In mass production conditions, this natural selection was replaced in the 1970s by the technology of standardization. The S. Colt factories were the first to start assembling goods from standard parts, which were previously checked by specially trained inspectors with so-called calibers for calibrating each product, thus establishing the correlation between the calibrated and real values. Unserviceable products were discarded. G. Ford and his close associate, scientist and engineer F. Taylor made an outstanding contribution to the development and final design of this type of quality management system. Thanks to them, the concept of manufacturing process management surfaced and, in some essential ways, has lasted up to the present time. It rests on a systematic approach, segregation of duties between managers and employees in ensuring quality, scientific labor rating, and a stand-alone independent product quality control system. The system makes sure that the consumer receives only high-quality products by identifying and cutting off defective ones.

Quality control of basic education is still based on the industrial principles of quality selection.The calibration function is performed by standard control-and assessment materials.The quality of basic education is established through “calibration” — interim examinations, state final certification, university enrollment testing. Specially trained employees carry out quality control. Just as different departments are responsible for the manufacturing process and product quality control in the industry, independent inspection authorities carry out the state quality control in education. The poor-quality products, or the learners who received low scores for the school-leaving examination, lose the opportunity to continue their university education. Their social chances reduce sharply. The entire current quality control system in education selects the “quality products” — the graduates with an excellent and good total score. The graduates with low scores are”rejected”. Just as Henry Leland, the founder of the “Cadillac” company, first-ever introduced the “go-on” and “not go-on” gage calibers in the automobile industry, so today, in the final assessment and go to university, a passing and failing grades are widely adopted.

The quality product selection system began to create problems as early as the 20s of the last century. Even then, in high-tech industries, the number of supervisors reached 40% of the total number of employees involved in manufacturing, causing cost escalation, and reducing economic efficiency. Similarly, the existing state system of quality control in education consumes a sizable portion of the ever insufficient educational resources. And yet the main challenge dwells not in the budget for this system maintenance but the very mode of operation. The rejected industrial products can be recycled. In education, the culling is applied, in fact, to people (although, of course, euphemisms shift the emphasis — the learning achievements are evaluated, not the individuals). But in sober fact, it is people (the students) who are sorted out by quality categories: high, average, low, passing, failing. This fact squarely indicates that the school fails to provide every learner with a quality education. The responsibility shifts to the learners. Educational and control authorities "cull out", separate achievers from non-achievers, just as the enterprise technical control department sorts out products by their further serviceability. The school produces a "rejected product," providing an education that does not meet established requirements. This state of affairs in education, although familiar, is inhumane and unacceptable from the standpoint of the digital economy. It is necessary to change the quality management system in education, abandon the industrial model of low-quality product rejection, and switch to a new quality assurance model.

A new approach to quality began taking shape in the 1920s in the light of q*uality management in manufacturing processes*. In 1924, Dr. Walter Shewhart, an employee of Western Electric, proposed a stability evaluation method known as Control Charts of W. Shewhart. The principle of method is quite simple: efforts should be focused not on removing low-quality products before they reach the consumer but on ramping up the output of high-quality products, eliminating the reasons that prevent this. The quality of manufacturing processes became subject to management. W. Edward Deming creatively developed and enriched the Shewhart approach. In 1950, he went to Japan, where his ideas found fertile ground. In the late 50s, Kaoru Ishikawa formulated and began to implement the concept of "all-Japan quality management" (*Country-wide Quality Control*) actively. The evolution of the ideas of W. Shewhart and W. E. Deming resulted in the concept of Total Quality Management (TQM — *Total Quality Management*). Today, it is widely recognized.

TQM is an advanced and efficient method of continuous quality improvement (CQI). Its dominant idea is that any company should focus not only on enhancing the high-quality output but also on the quality of the business process. Steadily upgrading the quality of all business processes is instrumental in improving product quality in manufacturing.

TQM stands on the ideas of Walter Shewhart. He considered variations, i.e., the manufacturing process malfunctioning, as the overriding reason for low-quality output. The failure to comply with the output parameters comes from deviations from the normal running manufacturing. It must be on a stable footing to ensure the required quality. According to W. Shewhart, the parameter variation is caused by two types of causes: root causes and special causes. Root causes are always there, and their elimination requires solutions aimed at changing the entire system. Special causes stem from the irregularities in the process, for example, low-quality raw materials, broken tools, insufficient skills of employees, etc. Rising to a higher quality level is doable only by eliminating an abnormal operation. Since variations, having a recurring nature, are a natural show of any process, then managing quality, in other words, eliminating variations, must be done continuously.

The concept of Total Quality Management (TQM) is widely applied in the economy. Its key-note is evident: to rise to high-quality outcomes, ensuring high-quality manufacturing processes is crucial. In education, this means to shift the focus of quality policy from evaluating educational outcomes to enhancing the quality of the learning processes (content and modes). As obvious as it may sound, nevertheless, the management activity has been so far entirely focused on evaluating learning outcomes and "calibrating" them – grading by quality levels. The reason is that a new quality policy is not feasible within traditional schooling.

9.4. Digital Education Quality Management

The opportunities for the widespread practical application of the TQM principles open up only with the transition to digital education; its content is modular-integrative and networked.

Adapting the TQM ideas to digital schooling can result in the concept of Total Quality Management for Digital Education (**TQMDE** — *Total Quality Management for Digital Education*). Here are some of its conceptual issues.

Eliminating variations in the learning process. The state educational standards set requirements for the outcomes of basic education. With that, its content and techniques are subject to constant variations that prevent from achieving a fail-safe high quality in each learner's training.

Common-cause variationsare inherent in having multiple methodical- and training sets for a single subject matter. Each methodical-and training set specializes in teaching children of a particular psychological makeup. Although, with mass schooling and its desk-based learning, where there is no reasonable opportunity for filling grades with the learners of a similar psychological type and the same level of needs and learning opportunities, the variety of methodical- and training sets does not help individualize learning and achieve high learning outcomes.

Special-causevariations in the teaching of a particular subject matter have always been another factor that drastically affects the quality of educational outcomes. They stem from communication between the teacher and the students in the classroom. They depend on dozens of different factors. Psycho-emotional factors: the moral and ethical atmosphere, the attitude of each student to the teacher and the attitude of the teacher to each student and to the class as a whole, the motivation to learn and teach, etc.Educational and methodological factors: a strong correlation between the lesson content and its teaching technique and the mental, intellectual, and emotional characteristics of each student; the students' readiness for the lesson; the teacher's attitude (personal and professional) to the content of the lesson, etc. Combinations of these and other factors can markedly change the nature of real-life learning processes, enhancing or debasing the quality of their outcomes and having a long-term negative impact on the quality of learning in general.

Special-cause variations in quality are eliminated in the digital school.The learner acquires new content items in the environment that suits him best.The Reproductive and Developmental Blocks of the DILM module help organize his learning process, manage the content of education, and set the pace and timetable for its assimilation.He is not distracted by the noise in class, and he is not influenced by other students who may not be as motivated to learn; he can listen to the teacher's explanations as many times as necessary. Comfortable environment, convenient time and place, the compelling cover of the topic, and the teacher's detailed explanations entirely exclude uncontrolled variations caused by unfavorable conditions of the learning process.Everything the teacher has to say in class, explaining new material and managing learners' activities, is contained in the auditory accompaniment of the DILM module. It is multi-layered and redundant: different teachers give different explanations of new material. The learner chooses from the auditory accompaniment what is engaging and understandable to him. The digital format helps to deliver complete and methodically arranged content to the learners. Besides, digital technologies customize the learning process in keeping with the learner's characteristics, allowing for choosing the level of mastering the topic and options for presenting its content.

Common-cause variations can be eliminated in digital education by retrieving uniform subject-based curricula arranged as digital integrative modules. The digital curriculum is a sequence of integrative learning modules. These modules are unified-standard: all students master the subject-based content from the same curriculum within the same DILM modules. However, no unification of the real processes of assimilation of learning material occurs. It is the digital modular structure that facilitates the full implementation of the elective education ideas. The DILM module offers vast opportunities for processing information and individualizing the learning process.The digital content of each topiccan be mastered at different levels of complexity and in different ways established by the appropriate teaching methods.With built-in elements of artificial intelligence, the DILM module interacts with each learner as a smart system.If a learner has difficulty mastering the content at a given level of complexity and for a given type of training, the DILM module automatically changes both. With that, it remembers the most successful options for mastering the content for a given learner. The modules are capable of machine learning. The entire digital subject-based curriculum is customized in keeping with each learner's individual needs and learning opportunities.

The digital modular structure eliminates the variations in the organization of the learning process. However, the variations themselves are natural and vital for thinking, communicating, and educating.In the digital school, they persist and thrive through the student's attitude to content. They are diverse and vary considerably depending on the student's individual characteristics, abilities and state of being, and the process of creating new information objects.In this case, the variability of the content and processes of its assimilation is pedagogically assured. The variations themselves shift from reducing the quality of learning to enhance the learner's thinking.

Documenting digital learning processes. As per the concept of Total Quality Management (TQM), documenting all the processes related to the manufacturing of products and affecting their quality is a prime driver of quality.For identifying and eliminating the causes that have led to the manufacturing of low-quality products, all business processes must be formalized, described in detail, and documented.Only in this case, with the causes turning into the subject for analysis, it becomes possible to pin down how this or that technological process occurred, identify failures and eliminate them.

Documenting digitally is a basic procedure for Total Quality Management for Digital Education (TQMDE).It is carried out by developing and continuously improving the DILM module.Each digital module contains two description plans: content-related and methodical. The first includes all of the learning material on the topic at different levels of mastery. It is designed for the learner. The systematic (methodical) description plan grows from documenting teaching and learning support materials. It contains sufficient information about what is being studied and how, and what personal potential is being delivered. This description plan is designed for teachers, methodology workers, heads of educational organizations, educational authorities, scientists, parents, and anyone else interested in education and can evaluate the quality of learning processes and make suggestions on their improvement.

Participation of subjects of educational relations in improving the quality of education. Documenting learning processes is essential to continuously improve the quality of the processes and the corresponding outcomes.The DILM content is open to all the participants in educational relations. Everyone can see and understand how the study of a certain topic goes. Accordingly, by virtue of their competence and interest, everyone can make suggestions on improving the content and organizing learning activities. The IDE receives these proposals. Its experts analyze them, refine them if necessary, and shape the DILM through their prism.The actors in educational relations should have a strong motivation for valuable innovations. If their proposals are introduced, their work is adequately paid in line with the pedagogical value of the solutions they offered.

In digital education, the system of Total Quality Management works well. Scientists can make suggestions for studying the latest scientific knowledge and technologies.Representatives of the business community call for shaping the required basic competencies.Teachers are constantly improving teaching methods and technologies. Apart from sharing their experiences, teachers also have the opportunity to introduce the best teaching techniques into the workings of mass schooling. Learners and their parents can communicate their wishes for each topic to study. School graduates have the opportunity to evaluate the knowledge gained from the standpoint of its utility for continuing their studies and career.

The TQMDE system is continuously in operation. It provides rapid updates of the content and teaching techniques, focuses efforts of all interested and competent actors on enhancing the quality of learning processes, allows for keeping and accumulating the best teaching experiences, promptly updates educational content in line with the latest scientific and technical achievements. The content of digital education is annually updated, and each new school grade receives an enhanced program to study a subject matter.

Chapter 10. Integration of Educational Networks

10.1. The Notions of "Educational Space" and " Educational Network»

The notion of "educational space" emerged in Russian pedagogy in the early 1990s under the direct influence of rapidly evolving informatization. The latter yielded new opportunities for education management, implementation of learning processes and did the groundwork for the integration of regional educational systems and educational facilities.Another factor behind the emergence and spread of the notion of "educational space" is economic and cultural globalization. The blurring of previously stable boundaries between social and cultural life brought the need to preserve and develop national education under multiculturalism and curricula variability. Creating a single educational space in the Russian Federation has become a priority in educational policy.

Humanitarian thinking borrowed the notion of "space" from physics. It refers to the three-dimensional continuum of the world around us where physical bodies are positioned and move. Space attaches integrity to the multitude ofreal and potential (conceivable) objects that fill it up.It allows man to act and orient in the environment: to correlate objects, analyze their real and virtual movements, evaluate forces applying to them, change the direction of forces, thus bringing objects to the required configurations.

Similarly, the educational space can be viewed as a three-dimensional social continuum. It includes various educational facilities, programs, standards, educational subjects, organizations that deliver curricula, scientific and other organizations that affect education in one way or another. The educational space is primarily a managerial category. By interpreting the educational space as the integrity of its constituent elements, we can position each and define the rules by which it can operate and develop without conflicting with the other components.

Many drivers contribute to developing the educational space. The most important among them is the evolving digital economy and the need for the rise of its lead resource — human capital. The digital economy requires life-long learning integrated into all economic and sociocultural activities. Man can build individual learning routes only in the educational space where it is easy to shift from one curriculum to another; their contents are coherent. Unlike the school, a stand-alone entity that transmits knowledge in a given place at a given time, the educational space entails personal enhancement through continuous, consistent, and successive competency-building over the life course.

A new-type economy calls for the spatial organization of education. It also provides the means to solve the problem. The educational space has a non-trivial network structure. It includes several types of networks: management networks, networks of educational and other organizations, networks of educational content, competency-based educational standards. Networks of educational content form the educational space. They take form primarily within the framework of the main educational programs. The network structure allows easy integration with other educational networks, as well as with social, economic and other. Herewith, the originality of teaching is not lost; learning opportunities are markedly enhanced. Networks have a strong internal structure and are fundamentally open to each other. The educational space is mainly shaped through network integration.

10.2. Opportunities for Education Networks Integration

Basic education networks are created primarily within the boundaries of primary, basic, and secondary education. The content of each level is networked on a modular-integrative basis according to relevant curricula. The unity of subject matter and interdisciplinarity, the systematic and consistent presentation of subject matters completed with comprehensive cross-curricular linkages shape the coherent content spaces at each learning level. A common network framework allows for integrating them into a single space of basic education.

The central technological unit for integrating basic education networks is the DILM.Interdisciplinary and intra-subject links are built into it. The latter are divided into the previous (the relationship of what is being studied to what has been previously studied) and the subsequent (the relationship of what is being studied to what is to be studied). Digital technology helps build a single line of content of subject matters from the beginning of their study to full completion, with access to any of the subject matter topicsat all levels of study if it is pedagogically appropriate and meets the learner's interests. Cross-curricular linkages may also be the previous (linking what is being studied in one subject to what was previously studied in another), the concurrent (linking what is being studied in one subject to what is being studied in another), and the subsequent (linking what is being studied in one subject to what is to be studied in another) ones. The modular-integrative organization of the content ensures the formation of a single network of basic education, with each component of the content of a subject matter connected with all components of both this subject matter itself and other academic subjects.

Educational networks can be integrated with other types of networks for pursuing productive teaching/learning objectives. For example, the social media. Students, mastering a new topic, are free to communicate and discuss educational learning activities and their contexts.Similarly, teachers use social networks to communicate, share experiences, enhance their professional performance, and find joint solutions to various teaching issues. The integration of educational content networks and social media creates a broad and free communicative environment and contributes to a more effective pursuit of learning objectives.

The network approach ensures synchronizing basic and extended education, including the activities of educational, cultural, sports, public, and other organizations.To that end, building extended education programs for children on a modular-integrative basis and placing them on the computer platform for basic education is necessary. Integration of basic and extended education networks enables creating a coherent space of education, awareness, and socialization of schoolchildren. In this space, tasks of consistent and successive building and development of basic competencies in line with the student's learning opportunities and requests can be successfully tackled.

10.3. Export of Basic Education

In the modern world, the export of education is a global business that aims to deliver educational services, profit-making, and expand cultural and economic ties. It is a crucial tool in geopolitics; it bigs up a country's status worldwide.

Approximately 70% of the content of education in public schools in different countries is the same. In the pre-digital age, it did not matter. In the global world of information, this fact shapes the environment for the export of education. The DILM content translated into foreign languages allows for trans-border learning and helps implement distant models to export educational services.Such models can be of two types: curriculum-based and competency-based.The first model entails the export of digital curricula, primarily natural science curricula, based on intergovernmental agreements.It will have understandable limitations related to the interests and security of states. The other — competency-based — model the export of servicesfor building basic competencies to perform activities in the digital economy.The exported service is rendered to and paid for by a given person, provided it is engaging, practical, and its content is interesting.

10.4. Man's Place in Digital Education

Man's place in the world, society, and education is determined by his activities, with the outcomes which matter to himself and others.What a man has done, lived through, comprehended makes for shaping his personal space.

Man's place is a personally created space proportional to himself, where his inner life flows objectively (meaningfully for others).It is a subjective space filled with personal meanings adapted to reality; this space is included in the objective space of social relations.

Man's place is a necessary component of the educational space. For attaching a real personal dimension to learning, it is crucial to create a place for each student. The absence of personal space in education is equivalent to a lack of personal meaning in learning.

he integration of educational and other networks ensures creating a coherent and open space of activity where information objects of various types are produced, driven by systemic knowledge. In this space, man occupies his own place. Man shapes his place and fills it in with his "pieces of work"— the results of his learning activities.

There is no environment for shaping man's place in reproductive learning because students do not create anything new that would matter to other people. Digital education facilitates accumulating personal learning achievements, which are subject to restructuring as soon as new achievements appear or man's attitude towards them changes; assessing learning outcomes, their interpretation, and their presentation to others if necessary or at will.Man's place is a space for storing, arranging, and systematizing new information objects that the student creates through e-learning. These objects reflect the development of his thinking, values, and competencies.

Man’s place is a specific, pedagogically and personally significant structural element of the educational space. It entails a certain didactic and technical organization, for example, as a Web-cabinet.

Web-cabinet — website — assigned personally to the student, a special virtual space that contains all personally and socially significant learning outcomes.It is continuously filled with new information that the student finds meaningful for himself and others.

To that end, Web-cabinet is similar to web-portfolio. Portfolio, as known, serves to record, accumulate, present, and assess individual student achievements of a student in a certain period of his studiesin a file folder format, which documents his experiences and successes.We can say that the portfolio is a prototype, an extremely simplified working prototype of a website.

The Web-cabinet is set up for a man when he enters the first grade of secondary school, remains with him throughout his life, is organized and filled by him personally. It can contain the learning outcomes achieved by the man at all learning levels, in all its forms and types, and all information objects created personally. The Web-cabinet represents a personal virtual interactive space.Throughout life, the man repeatedly completes and rebuilds it, configuring his Web-cabinet in line with what he needs at a particular moment: a study, a house, a library, a laboratory, etc.Within this space, there are functionally diverse spatial areas: a desktop, a portfolio for presenting educational achievements, room for games, communication, recreation, and other areas that simulate real and conceivable circumstances of human life.His digital avatar is free to move between different areas of personal virtual space.

The Web-cabinet serves as an entry (exit) point to the digital learning space. It is instrumental in integrating educational networks: it connects them in a unique way that meets the needs and serves each learner’s goals. Actually, the very integration of networks is crucial for a man to have the opportunity to shape and develop personal space in education and culture over his lifetime. The Web-cabinet is also vital for functioning and evolving digital economic activities. It makes for the personalized accumulation of human capital, for its self-assessment and management in line with the professional and personal tasks that an individual pursues at one time or another in his life.

Conclusion

Setting up a digital school is a grand and promising socioeconomic project. A complex problem requires simple and straightforward solutions that reconcile the interests of all for whom it matters. The new type of mass school is one of the key factors in further developing the digital economy and the information society at large. It primarily affects the quality of digital economy personnel, the formation and successive building of basic competencies necessary to perform a productive and responsible activity in the digital world, the achievement of the integrity of public consciousness by integrating its various forms, the development of methods and technologies of thinking and human activity.Addressing such a demanding, complex socioeconomic and humanitarian challenge nowadays no longer faces obstacles caused by the lack of required expertise; the scientific theory opens up a real possibility to set up a digital school in a short-term historical perspective.

New education requires new content. Current subject matters are retained in the digital learning space, guaranteeing the continuity of the traditional and digital schools.Supplementing and updating the traditional subject-based content is organized through 1) interdisciplinary integration, 2) modeling real-world objects by applying systemic knowledge from diverse subject domains, 3) creating new information by the teacher and students through the learning activity, 4) updating educational content within the DILM by all competent and interested actors. The content of digital education becomes consensual.

The coherent content of digital education is networked: each integrative module is connected to all other complex sequences of intra-subject and inter-subject communications.In this way, an artificial neural network (ANN) of education emerges — a didactic model, together with its software and hardware, built on the principle of organization and functioning of biological neural networks of the human central nervous system. The artificial neural network (ANN) of education continues the brain activity of educational subjects and significantly expands their intellectual capacity. It represents a socially organized form of artificial intelligence based on national and world culture and its highest humanistic values.

Continuity with the existing school makes the transition to digital education smooth, fast, and conflict-free. Digital modules can be developed, implemented, and tested in the real-time learning process, not violating its integrity and a day-to-day learning activity pace. Each DILM module corresponds to a specific study topic of the curriculum. As the digital integrative modules start revealing the content of an increasing number of study topics presented in paper and digital textbooks in a more comprehensive, in-depth, and engaging way, a natural transition to a new type of education will occur.

Changes in school are positive if teachers support them. For them, the transition to digital education brings no additional loads or sway-away from conventional professional practices. Above all, the teacher becomes free from monotonous work, day after day, year after year of repetitive activities. The teacher's socioeconomic status rises objectively, and the opportunities for creative activity, personal and professional growth grow markedly. Teaching in a digital school acquires a sustainable creative character.The authority of the teacher grows, and the socio-psychological atmosphere in the school improves.