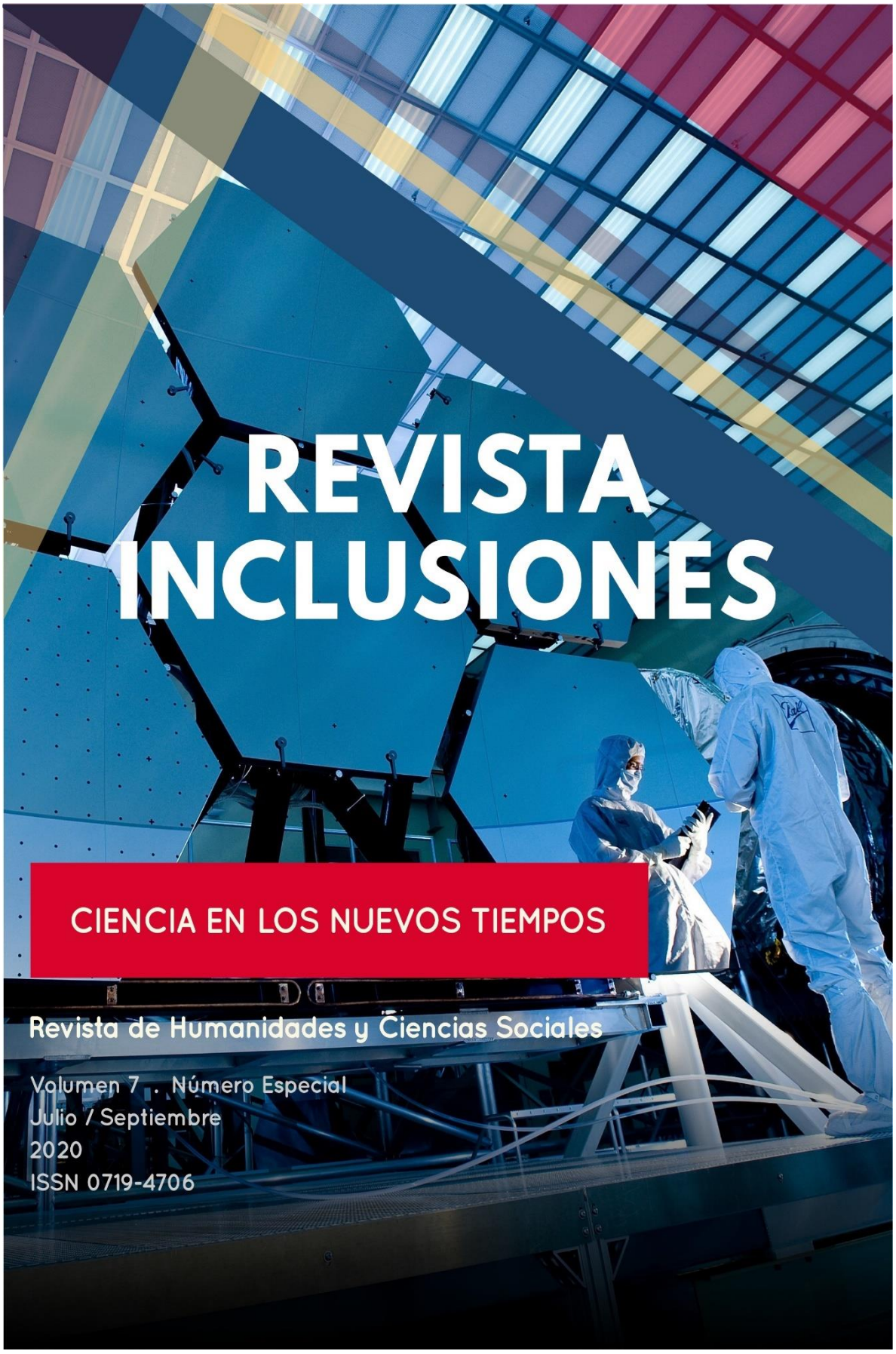

REVISTA INCLUSIONES

CIENCIA EN LOS NUEVOS TIEMPOS

Revista de Humanidades y Ciencias Sociales

Volumen 7 . Número Especial
Julio / Septiembre
2020
ISSN 0719-4706

REVISTA
INCLUSIONES
REVISTA DE HUMANIDADES
Y CIENCIAS SOCIALES

CUADERNOS DE SOFÍA
EDITORIAL

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CUADERNOS DE SOFÍA EDITORIAL

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REVISTA INCLUSIONES
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BIBLIOTECA UNIVERSIDAD DE CONCEPCIÓN

REVISTA INCLUSIONES
REVISTA DE HUMANIDADES Y CIENCIAS SOCIALES

CUADERNOS DE SOFÍA EDITORIAL

ISSN 0719-4706 - Volumen 7 / Número Especial / Julio – Septiembre 2020 pp. 300-312

THEORETICAL FOUNDATIONS OF THE COMPLEMENTARY SEMANTIC APPROACH IN EDUCATION

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Fecha de Recepción: 13 de marzo de 2020 – **Fecha Revisión**: 22 de mayo de 2020

Fecha de Aceptación: 29 de junio de 2020 – **Fecha de Publicación**: 01 de julio de 2020

Abstract

The article presents the results of research on resources for improving the quality of the educational process in secondary schools when using a complementary semantic approach. The article is aimed at the uncovering and theoretical justification of ways that will help the teacher to effectively convey information to the pupil while helping the child to quickly and efficiently acquire this information based on own life experience. An ergonomic image-spatial organization of the educational process, whose semantics is demonstrated in the article, can become an effective mechanism for modernizing education. The authors believe that one of the reasons for the problem faced by Russian schoolchildren when testing using the PISA for Schools model and checking the level of mathematical, natural science, and reading literacy of children, is the lack of teachers' care about the perception of information by each pupil. The complementary semantic approach to the construction of the educational process is aimed at solving exactly this problem.

Keywords

Complementary semantic approach – Recursion – Spatial model – Education – Art

Para Citar este Artículo:

Kashekova, Irina Emilievna. Theoretical foundations of the complementary semantic approach in education. Revista Inclusiones Vol: 7 num Especial (2020): 300-312.

Introduction

The search for new approaches that are consistent with contemporary culture and meet the needs of present-day childhood, forced the authors to turn to a new complementary semantic approach in education. The conducted research has shown that pedagogical technologies and methods based on the proposed approach can help teachers to coordinate efforts in creating conditions for harmonizing the external physical space, in which the child lives with his inner, psychological world while helping the child to learn more information without overload and emotional shocks.

The timeliness of a radical revision of the educational process structure and conditions is confirmed by many factors, such as the change in the way of transmitting and storing information (from verbal to visual), the globalization of world processes, the rapid development of technology, and the general weakening of the physical and psychological health of school-age children.

Today, for many it is clear that humanity is on the verge of a colossal restructuring. According to the American philosopher, sociologist and futurist, the creator of the concept of post-industrial society, A. Toffler, civilization is on the crest of the Second Wave, and about 2025 will enter the Third Wave, i.e., if the estimations of the scientist are correct, then there will be a change of civilizations. This will be the beginning of the Third civilization since the appearance of a human on Earth (the First Civilization was agricultural, lasting from primitive times to the 18th century; the Second Industrial Civilization was from the 18th century to this day)[1]. A similar theory was put forward by Russian mathematicians and synergetics. At the end of the 20th century, they anticipated that in 2025, civilization, as an unstable nonlinear system, will come to the point of bifurcation that will result in either the Apocalypse or "access to a new attraction center, a new attractor"[2].

Since education is most closely related to the type of current cultural and civilizational process, one can also talk about a radical change in education. It is still difficult to say, whether this change will be systemic or occur at the level of individual subsystems but it is obvious that the explorations ongoing during the past 30 years in the theory and practice of education are not accidental but a prolonged preparation for fundamental changes. It is equally obvious that in the context of endless information flow and rapid change of opinions about the capabilities of industrial, bio- and nanotechnologies, sometimes completely rejecting the usually established laws, the reality of achieving the goal of basic education to teach everyone everything is disappearing. This means that it is necessary to *sift* and/or *condense* the content of education and reconstruct its organization. The complementary semantic approach in education is aimed at solving exactly these problems.

The PISA for Schools educational quality assessment tool developed by the Organization for Economic Co-operation and Development (OECD), checks the level of mathematical, natural science, and reading literacy of children aged 15-16 years to determine their ability to apply in life situations the knowledge obtained in the educational process. The present research, based on the obtained theoretical data, represents the educational process resources that will help the teacher to effectively convey information to

[1] A. Toffler, The Third Wave: The Classic Study of Tomorrow (NY: William Morrow and Company, 1980).
[2] A. V. Voloshinov, Matematika i iskusstvo (Moscow: Prosveschenie, 2000).

the pupil while helping the child not only to master this information efficiently and quickly based on own life experience but also to operate it depending on specific life situations.

Since the beginning of the intense work of the pedagogical community on the modernization of primary and basic general education, many approaches, technologies, and methods have been developed that in one way or another can make the education process more effective. However, as a rule, innovations are local and tied to the personality of the teacher or scientist who successfully implements the innovation. Perhaps, this is the main reason why, despite the positive results, innovations do not get widespread in mass schools.

In contrast to many innovations, the complementary semantic approach to the pedagogical process organization claims to be systematic and comprehensive.

Problem statement

In the history of mankind after the Enlightenment, a time before which science and art were not separated, there were many lonely voices of outstanding humanist scientists and cultural figures, who did not accept the artificial separation of the two leading spheres of human culture, and considered it wrongful; among them are D. Likhachev, J. Pretti, C. Snow, P. Florensky, etc. Relating science and art, the poet V. Bryusov wrote: "Art, in particular poetry, is an act of knowledge; thus the ultimate goal of art is the same as that of science, i.e. knowledge.... If poetry, as a science, is a form of knowledge, then what is the difference between scientific knowledge and knowledge through poetic creativity? They differ exclusively by the method. The method of science is analysis; while the method of poetry is synthesis"[3].

Certainly, one can say that analysis and synthesis are present both in science, as well as in art. It is rather a matter of sequence of actions: art, through the particular, establishes the typical, while science through generalization comprehends the particulars. And perhaps it is at the intersection of these ways of understanding the world that truly new knowledge is born. In a long-standing article by an English writer, a physicist by education, C. Snow titled "The Two Cultures", the author just refers to the opposition of science and art as two opposite, hostile cultures: "It seems that there is no ground at all for unifying two cultures... this is not only sad but also tragic… For our mental and creative activities, this means that the richest opportunities are wasted. The collision of two disciplines, two systems, two cultures, ... cannot fail to strike a creative spark"[4].

The search for the most effective ways to transfer knowledge, assimilate it, and use it in contemporary education may eventually lead to a change in the educational paradigm. Without setting such a global task, the authors formulate the problem of the present research based on the idea of unity, complementarity, and a semiotic nature of culture as follows: how to change the content and process of pedagogical implementation using a complementary semantic approach in education, spark pupils' interest in learning the world, develop a sense of belonging and responsibility, and ensure the development of creativity.

[3] V. Ya. Bryusov, Izbrannye sochineniya v 7 tomah (Moscow: 2, 1955).
[4] C. P. Snow, The Two Cultures (Cambridge: Cambridge University Press, 1993).

Research problems

What is the complementary semantic approach in education? What are its mechanisms and functional concept? To what extent can it change the education content and process? What will it give to the teacher, the pupil, and the society?

Research goal

Interpreting and providing scientific substantiation of the resources for the complementary semantic approach in updating the content of education and the pedagogical process.

Research objectives

– Substantiating pedagogical expediency and consistency of the complementary semantic approach;

– Defining the principles of implementing the complementary semantic approach in the educational process;

– Identifying interdisciplinary ways of designing the semantics of the educational process, creating the semantic space of the pupil, and the possibility of compacting educational information.

Methods

The concept of *complementarity* was introduced into the Russian pedagogical science more than 15 years ago and covered in the works of I.V. Galkovskaya (2005), S.T. Dzhaneryan (2005), S.Yu. Rudnik (2008), E.V. Dolzhenkova, M.A. Kazakova (2015), T.A. Yuzefavichus (2015), and O.Yu. Nikolaev (2017). When using the meaning of the concept of *complementary* as a "compliment, mutual conformity, the relationship of complementary structures", scientists relied on additionality or its interpretation in chemistry, molecular biology, and genetics. In physics, the principle of complementarity, formulated by N. Bohr as far back as in the first third of the 20th century, is one of the central principles of quantum mechanics and has acquired the status of a methodological and heuristic principle of science. The most imaginative and accessible definition for a nonspecialist in this area was given by J. Watson: complementarity is formed "if the surfaces of molecules have complementary structures so that the protruding group (or positive charge) on one surface corresponds to the cavity (or negative charge) on the other. In other words, the interacting molecules must fit together like a key to a lock"[5].

The semantics of the concept of *complementarity* includes two most pronounced meanings: complementary, in the sense of *auxiliary* and polysyllabic, or *acting conjointly*[6]. Both interpretations are used in the context of the present research. Dzhaneryan and Yuzefavichus consider complementarity in education most commonly and widely.

[5] J. D. Watson, Molecular Biology of the Gene (Amsterdam: Benjamins Publishing Company Philadelphia, 1965).

[6] S. Yu. Rudnik. Komplementarnye programmy kak obrazovatel'nye programmy novogo tipa", Information humanitarian portal: Knowledge. Understanding. Ability num 2, Pedagogy. Psychology (2008). Retrieved from http://www.zpu-journal.ru/e-zpu/2008/2/Rudnik/

Dzhaneryan studied complementary systems in pedagogy[7]. Yuzefavichus investigated the invariant principle of building knowledge about educational activities, ensuring its systematic completeness. Considering professional and pedagogical errors, the author substantiates the idea of "productivity of complementarity for solving the problem of updating the methodological tools of pedagogy adequately in compliance with modern realities"[8]. She suggests understanding complementarity in pedagogy as "a way of existence of educational activity as an integral process in which pedagogical phenomena are in a relationship of complementary opposites"[8]. The principle of complementarity in pedagogy is interpreted by Yuzefavichus as "a methodological requirement to apply two mutually exclusive sets of classical pedagogical concepts to describe educational activities" [ibid.]. This is quite consistent with the research conducted by the authors earlier, where without touching on the concept of *complementarity*, the school's educational system was considered as an integrated educational space (*monoseparable integrity*)[9]. This has been justified by the fact that an ideal integrated educational system should consist of a large number of semiotic subsystems, it is open to the information environment, and its main characteristic is language diversity. At that, the law of semiotic heterogeneity acts as the beginning of the integration of education, as well as any other integration, since in the integration of educational space, as well as in complementary semantic space, there are many options of various components combinations with different communication types having spatial characteristics – linear and nonlinear, discrete and continuous.

The strategy of applying the semantic approach is currently used as a convenient and popular means of research in many fields of science and culture, namely mathematics, philology, cultural studies, computer science, sociology, history, psychology, etc. In pedagogy, the semantic approach helps understanding the essence and laws of nature, physical phenomena, historical events, and the social foundations of human life.

According to the American mathematician and logician R. Montague, the semantics of words, images, and information, in general, is revealed not so much in the designation of objects and phenomena as in their instrumentality[10], their ability to be mechanisms for creating new words, images, and interpretations, which are often the offspring of associative thinking. It is known that the languages of sciences are discrete (linear-discontinuous), while the languages of art are continuous (spatially continuous). The unity of these languages can ensure the integrity and stability of relations in the educational space of the school. Thus, education based on a complementary semantic approach using the oppositional languages of science and art will assuredly develop (Fig. 1).

[7] S. T. Dzhaneryan, “Sistemnyj podhod k izucheniyu professional'noj YA-koncepcii”, Application: the Humanities. Bulletin of the Orenburg State University. num 4 (2005).

[8] T. A. Yuzefavichus, “Ideya komplementarnosti v pedagogike”, Bulletin of the Moscow State University. Series: Pedagogy. num 2 (2015).

[9] I. E. Kashekova, Sozdanie integracionnogo obrazovatel'nogo prostranstva shkoly sredstvami iskusstva. (Monograph. Moscow: RAO Publishing House, 2006) y A. F. Losev, Dialektika mifa (Moscow: Azbuka, 2016).

[10] R. Montague, The proper treatment of quantification in ordinary English. Approaches to Natural Language: Proceedings of the 1970 Stanford Workshop on Grammar and Semantics. Ed. J. Hintikka, J. Moravcsik, and P. Suppes (Dordrecht: Reidel, 1973).

LINK TYPES OF INTEGRATION SPACE COMPONENTS

- **Linear and nonlinear**
- **Discrete and continuant**

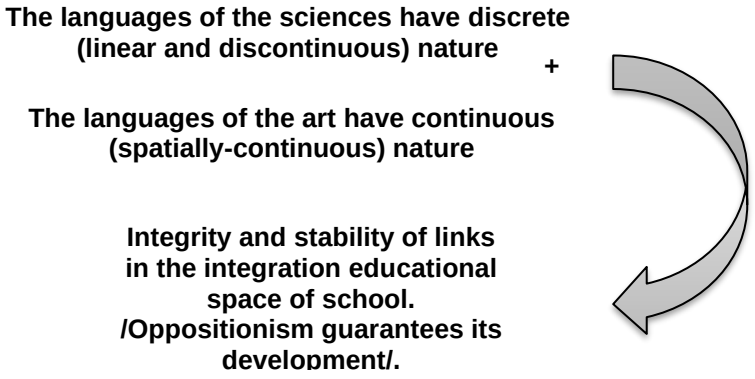

Figure 1
Relation types in the integrated educational space built on a complementary semantic approach

Bohr's statement about the effectiveness of the mutually exclusive use of two languages originating from ordinary logic to comprehend any integral phenomenon reproduced in the semiotic system expands the logical structure of the subject's language. This phenomenon was called by an outstanding physicist the principle of additionality or complementarity. The term *complementarity*, which Bohr used to reveal the relationship between a particle and a wave in the microcosm, he learned from the psychological literature[11]. Using the principle of complementarity, it is possible to explain any phenomenon in different languages, which allows a panoramic view of the phenomenon[12]. In this case, the information will be more complete and the interlocutors will understand each other more easily.

While considering complementarity in education as a universal cognitive strategy for the development of education[13], both in the scientific and practical range, the desire to use the constructive features of complementary systems, namely, the complementarity of opposites, becomes understandable[14]. The semantic approach is no less effective for understanding the essence of society and culture, comprehending the laws of nature and social phenomena[15].

[11] F. Capra, Uncommon Wisdom (London: Rider, 1988).
[12] I. E. Kashekova, Sozdanie integracionnogo obrazovatel'nogo prostranstva shkoly sredstvami iskusstva. Monograph (Moscow: RAO Publishing House, 2006).
[13] O. Yu. Nikolaev, “Primenenie principa komplementarnosti v pedagogicheskoj deyatel'nosti”, Bulletin of the Buryat State University. num 1 (2017).
[14] I. V. Galkovskaya, “Dopolnitel'nost' kak vedushchij princip processa stanovleniya komplementarnyh obrazovatel'nyh system”, Bulletin of the Orenburg State University. Application: the Humanities. num 4 (2005).
[15] D. V. Sergeev, “Strategii primeneniya semanticheskogo podhoda k issledovaniyu obshchestv i kul'tur”, Contemporary Issues of Science and Education. num 6 (2012). Retrieved from: http://science-education.ru/ru/article/view?id=7699

Thus, in a complementary semantic approach to education, complementarity ensures the relationship and mutual reinforcement of the educational process components, while the semantic level reveals the semiotic essence of the information received, allowing its variable interpretation from different perspectives of an artistic and expressive symbol. The complementary semantic approach, which uses the reserves of associative thinking, contributes to the *unfolding* and enrichment of visual information with new images.

The complementary semantic approach in the pedagogical process is provided by the following principles: interaction and mutual reinforcement; recursiveness of building new knowledge; operating with signs and symbols; spatial modeling of the educational process; organizing value of associativity and improvisation of images.

The **principle of complementarity** is the first and leading principle of implementing the complementary semantic approach in the educational process. According to A.V. Anisimov, who studied in the last quarter of the 20th century recursive transformations of information as specific, algorithmically constructed ways of organizing complex systems, the **principle of recursiveness** is the second[16]. Anisimov gave examples of recursion in various fields of knowledge and art, as well as in the formation of people's psychic activity. The possibility of implementing the idea of creating recursive modeling programs for artificial intelligence was revealed by him using recursive methods to analyze and formalize (writing in the form of signs) scientific and artistic texts, including visual art and music. Two important points can be effectively used in the formation of pupils' intelligence in the context of an overabundance of information: 1) using generalized, stylized images of the characters to record information; 2) using parallel recursion, which can allow achieving a particularly strong impression of a scientific or artistic text[17].

Recursion is one of the basic concepts of algorithm theory. A recursive system can constantly grow and become more complicated by copying itself, at that, the growth process is organized, and all subsystems are constantly interacting. If perceiving complementarity in the form of puzzles that joining and complementing each other create the right picture, it becomes clear that the most general initial knowledge of a child, perhaps obtained based on the life experience, is gradually complemented by elements of theoretical knowledge and methods of practical activity. At that, they are attached not formally, but tightly filling in gaps and gradually adding to the picture of the world. Several new *puzzle elements* are attached from different sides to each new *puzzle element*, etc. In other words, each new knowledge is simultaneously the key to the next knowledge, at that the new knowledge is increased spatially rather than linearly just in one direction. Here one comes up to two more conclusions: 3) each new knowledge can be supplemented *from different sides,* i.e. is viewed from the standpoint of different sciences and arts; 4) multiple extensions of new *puzzle elements* can change the original system unrecognizably.

Computer scientists, who are engaged in artificial intelligence, use recursive methods of solving problems, create algorithms that simulate human creative processes. Anisimov gives a lot of examples of recursion: from the development of the Universe to recursive schemes of literary works, the interaction of themes in music, in the admissions of the laws of linear and aerial perspective in painting. The universality of this interdisciplinary phenomenon allows assuming the effectiveness of its use in the pedagogical process.

[16] A. V. Anisimov, Informatika. Tvorchestvo. Rekursiya (Kyiv: Naukova Dumka, 1988).

The development of the theory of recursiveness was continued in the works of A.V. Lichutin, who notes the self-reproducing nature of recursive structures, their complication in the algorithm of self-unfolding through self-repetition. Moreover, the complication occurs according to its own regularity – "a finite (but admitting changes) rule which is accessible to *rational knowledge*"[17]. Isn't this an image of the individual trajectory of a child's development?

Considering the approach of *circular closure* of knowledge, Lichutin refers to M. Heidegger's expression: "clarifying rather than explaining." In the pedagogical process, one can imagine this as the **principle of alternative solutions**, which provides clarifying and encouraging the pupil to research, integration, i.e., stimulating thinking and intuition, searching for associations, and therefore developing creativity, rather than bottom-line explanation which is presented by the teacher as a set of axioms. Another important point in the work of Lichutin is a theoretical rehabilitation of the "so-called *thinking by analogy*, which is mostly evaluated as a search for *deep parallels* between phenomena"[18]. Thinking by analogy or **associative thinking** is performed when **operating with images** that are available in the memory of a person. An image is an embodied idea. According to Losev "... there is absolutely nothing in the *image* that would not be in the *idea*. *The image* speaks of an *expressed* idea, and it is enough just to contemplate the very image.... in order to grasp thereby the idea".

Therefore, any idea (including scientific one), at least in the most general sense, can be expressed through an image. The image is immaterial, but it can only be seen in the case of material embodiment. Images are unstable, dynamic, changeable, and perceived differently by different people. Are not these qualities of the image similar in character to contemporary culture, in which visual perception has become the norm of everyday life, the visual image plays a crucial role in technology, science, and even in everyday life? The problem of perception and creation of a visual image has become more relevant than ever before. In school education, visual culture and visual literacy can only be developed by just one subject – visual art, but visual images and semantics of signs can be used in all subjects since the figurative form of information representation is much more compact than spoken form.

The introduction of the interdisciplinary concept of image in the content and methods of teaching is one of the main mechanisms of the pedagogical process based on a complementary semantic approach. After all, an image is both the appearance of a real object and description that conveys an idea of it, a subjective judgment, a metaphorical synthesis, a model of what exists, a generalization expressed realistically or hypothetically. The strength of the image is its interdisciplinarity, it can be perceived by both the senses and consciousness. In the mental image of an object, the real and the abstract are integrated, particular features or properties are concretized, new imaginary models are formed which can be expressed by both semiotic-linguistic and visual means. The relevance of using the universal concept of *image* in education is confirmed by its wide application both in the art (artistic image) and in science (symbolic image systems, and semiotic models).

[17] A. V. Lichutin, Ontologiya rekursivnyh struktur (Ph.D. thesis in philosophy. Arkhangelsk: Pomor state University named after M. V. Lomonosov, 2006).

[18] I. E. Kashekova, "Realizaciya mezhdisciplinarnoj kross-kul'turnoj pedagogicheskoj tekhnologii «ART+» na osnove vzaimodopolneniya estestvennonauchnogo i gumanitarnogo znaniya", Collection of scientific papers: Technologies and Innovations in the Practice of General Education Schools. Compiled by E.M. Akishina, D.V. Pol, and E.V. Romanova (Moscow: The Institute of Art Education and Cultural Studies of the Russian Academy of Education, 2016).

Besides, the image adds personal meaning to the new information and ensures the interconnection and complementarity of scientific and artistic knowledge of the world, i.e. the complementarity of the knowledge process. Psychologists note that "a person learns about the surrounding world through images, rather than by body of knowledge. Knowledge organizes and structures images into a system" (V.P. Zinchenko)[19]. Through the image and the associations it evokes, the new knowledge is incorporated into the child's psychological space. In this case, it not only affects the inner world of the pupil but also forms it.

Given the nature of contemporary culture with its endless information flows, the priority of visual perception, striving for integration, a strongly expressed semantic origin, and new forms of mythological perception of the world, the authors have developed and tested in practice "ART+" cross-cultural teaching method based on a key concept of *image*.

The ambiguity of the concept of *image* and the role of imaginative thinking in the mental life of a person can make it a key pedagogical mechanism of education.

Results

Due to the complementary semantic approach, it is possible to get a comprehensive educational system with fundamentally new features. The semantics of the image-spatial organization of the educational process will serve to increase its effectiveness since it is primarily associated with the visualization and psychologization of the educational content and methods of its transmission. Visualization is important and natural for today's child since the contemporary world appears to him in the form of a visual sign-based image. Psychologization is important since it allows constructing the ways to transmit information based on the internal psychological space of the child, the ability of the teacher to mark the boundaries of this space so that it is comfortable for the learner.

The use of a universal semiotic construct in the educational process using vectors of a three-dimensional rectangular coordinate system and forms of information transfer, such as a graphic sign and an artistic composition, creates expressive memorable images. According to A.Ya. Brodetsky, a human exists simultaneously in two spaces: external (physical) and internal (psychological). Physical space is a limitless real space whose coordinates are height, width, and depth. Psychological space is exactly the space of human activity that affects emotions[20]. The boundaries of psychological space are determined by the type of activity. In education, this statement is confirmed by the potential of the activity approach, since it is the activity that forms the psychological space or the space of emotions. Due to the psychological space coordinates, human perceives the world emotionally. Its vectors are directed towards vertical, horizontal, and sagittal. Creating conditions in the education process for harmonizing the external physical space in which the child is with his inner, psychological world will allow him to master more information without overloading and emotional shocks.

Lotman Yu.M. noted that "spatial modeling of concepts that do not have a spatial nature themselves" was important for the art[21]. Their perception generates a psychological

[19] V. P. Zinchenko, Psihologicheskaya pedagogika. Materialy k kursu lekcij. Part I. Living Knowledge (Samara, 1998).
[20] A. Ya. Brodetsky, Vnerechevoe obshchenie v zhizni i v iskusstve (Moscow, 2000).
[21] Yu. M. Lotman, Struktura hudozhestvennogo teksta. (St. Petersburg: Art-St. Petersburg Publishing House, 1998).

response of the viewer and the emergence of associations. This leads to **three concepts** that can become **key-note for education**, namely, ***spatial modeling of concepts***, the ***psychological response***, and ***associations***.

Associations that appear and persist in human sensations under the influence of external coordinates are the psychological space vectors. In education, as well as in art, any meaning can be expressed using space modeling, especially since space can have a metaphorical or iconically-spatial character. This feature of spatial models in art differs from other forms of sign-based modeling. Indeed, "the image of the Universe is easier to dance than to tell, to draw, mold, or construct than to logically explicate"[22].

In art, the artist focuses the viewer's attention on certain elements, highlighting their significance in the story of the artwork. Thus, an artwork evokes certain **associations** and experiences. Vertical and horizontal lines contribute to the work of thought, while the sagittal going depthward encourages an emotional attitude to the image. The teacher uses an expressive image, metaphor, and associations to focus pupils' attention on certain elements, highlighting their significance in educational information. The semantics of the educational process includes a dialogue that is built:

- at the content level – between science and art, theory and practice;

- at the semantic level – between oppositional pairs within the psychological space of the pupil; an idea and an image; a thought and a feeling.

- at the communication level – between the used languages and semiotic systems of information representation; between participants of the educational process.

Thus, the **semantics of the educational process** is built along the all three coordinates (Fig. 2)[22], the vertical line can be associated with the knowledge vector (content), the horizontal – with the practical vector (methods of activity), and the sagittal – with the psychological vector (perception: images and associations)[2]. This is supported by the principle of **spatial modeling of the educational process**.

In a three-dimensional rectangular coordinate system, the vertical and horizontal lines contribute to the work of thought while the sagittal going depthward, stimulates the emotional attitude to the image.

[22] I. E. Kashekova and E. A. Kononova, “Cognitive factors of "Art+" cross-cultural pedagogical technology”, International Journal of Innovative Technology and Exploring Engineering (IJITEE). Vol: 9 num 1 (2019): 1305-1311.

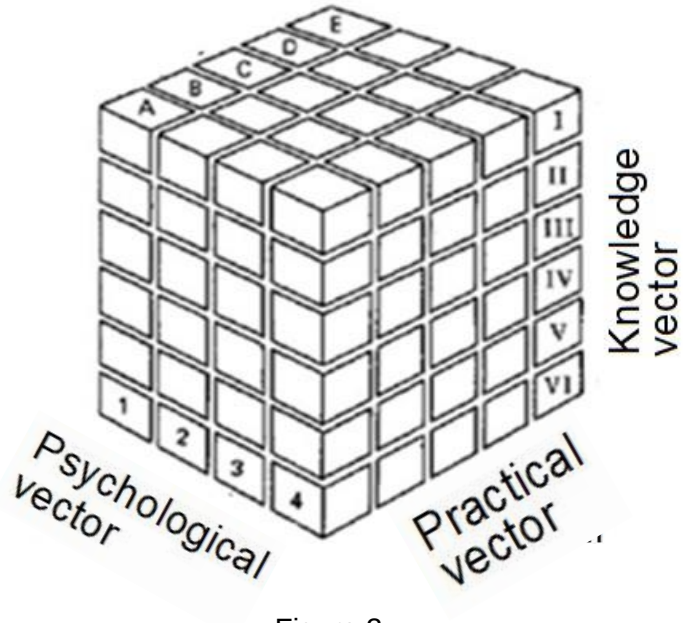

Figure 2
A spatial model of the educational process

Conclusion

Uncovering and substantiating scientifically the resources of complementary semantic approach in updating the content of education and teaching process have allowed revealing their pedagogical expediency and consistency, identifying principles of implementation in the educational process of spatial modeling of the educational process, complementarity and intersystem crossing of science and art, interdisciplinary recursiveness, visualization of a sign-based image, alternative solutions, and associative bonds. The main mechanisms for implementing the complementary semantic approach are interdisciplinary ways to create a semantic space for a pupil using the "ART+" cross-cultural pedagogical technology, which creates opportunities for compacting and acquiring personal experience when perceiving educational information, and the introduction of the interdisciplinary concept of the image into the content and methods of teaching all subjects.

Acknowledgments

The authors express their gratitude to the Director of the Institute, E.M. Akishina and colleagues E.S. Medkova, E.N. Piryazeva, and E.A. Kononova for their fruitful joint work on the project.

The results of the study are obtained as part of the state task of the Ministry of Education of the Russian Federation on the project "Theory of a complementary semantic approach in education" for 2020.

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