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KNOWLEDGE VISUALIZATION OF SCHOOLCHILDREN AS A TOOL FOR DEVELOPING COGNITIVE SKILLS IN MODERN NATURAL SCIENCES EDUCATION

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Among the essential characteristics of the modern educational process in Ukraine are the development of information technology, the perception of the Internet as an integral part of our lives, the active introduction of blended learning, innovations in the field of information transmission, based on the mechanisms of visual perception of information and visual and imaginative thinking. All of this has led to qualitative changes in the development of education and the social consciousness of its students. To identify and substantiate the most effective visualization techniques for mastering the content of natural sciences subjects as well as future natural sciences teachers professional and methodological training based on the analysis of existing visualization techniques and their expert evaluation. Data collection was carried out using the methods of questionnaires, expert evaluation, diagnostic work. The five most effective visualization techniques for ensuring a holistic perception of knowledge through a combination of logical and imaginative thinking have been identified. It was outlined and experimentally validated the pedagogical conditions for the effective use of scribbling technique in the process of natural sciences studying.

Keywords: *quality of education, pedagogical conditions. schoolchildren, visualization techniques, scribbling.*

Introduction. Our time is characterized by extreme variability and uncertainty in the conditions of both natural and social processes. Among the essential characteristics of the modern educational process in Ukraine are

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the development of information technology, the perception of the Internet as an integral part of our lives, the active introduction of blended learning, innovations in the field of information transmission, based on the mechanisms of visual perception of information and visual and imaginative thinking. All of this has led to qualitative changes in the development of education and the social consciousness of its students.

As you know, visualization is inherent in most areas of human activity. Education has not been left out either. Knowledge visualization is an important component of the modern educational process, which aims to improve learning efficiency by presenting information in a clear and accessible form. In the context of education in Ukraine, this issue is becoming increasingly important due to the transition to a competency-based approach, the integration of digital technologies, and the reforms of the New Ukrainian School. The Google search engine provides more than 800,000 results and over 150,000 results for the query 'visualization in the educational process'. This is a clear confirmation of the relevance of the phenomenon and process of visualization in modern society.

The significance of the issue of knowledge visualization has been revealed in our publications (Stepanyuk & Kartashova, 2023). We associate it, first of all, with the updated essential characteristics of the modern student (Z Generation), the change of the subject-subject educational paradigm to a polysubject one (student, teacher, information educational environment as a networking subject of the educational process), the need to intensify learning as one of its effective characteristics. Intensification is possible thanks to visualization, which presents large amounts of information in a concise, condensed, logically organized form that is adequate to human psychophysiology. Considering that the amount of educational material and the time given for its study are relatively fixed, it can be argued that technologies (techniques) for visualizing educational information are becoming crucial.

The issue of visualization of the educational process in the New Ukrainian School is quite relevant, as scholars believe that it contributes to improving the quality of educational services (Zhytienova, 2016; Silkova & Lobach, 2018; Onofriichuk, 2020; Honcharova, 2021). However, most researchers consider the issue in the context of studying mathematics, foreign languages, and biology without their logical coordination with the teachers training to implement cognitive visualization technologies in science education. Therefore, **the article aims** to identify and substantiate the most effective visualization techniques for mastering the content of natural sciences subjects as well as future natural sciences teachers professional and methodological training based on the analysis of existing visualization techniques and their expert evaluation.

To achieve this, it was necessary to address the following tasks:

1. To identify and characterize the visualization techniques that are most often used in educational practice.
2. To study the state of the issue implementation in the context of pedagogical activity.
3. To outline and experimentally validate the pedagogical conditions for the effective use of scribbling technique in the process of natural sciences studying.

Analysis of research and publications. The analysis of literature sources has shown that the possibilities, advantages and disadvantages of visualization in the educational space have been widely discussed over the past decade in Ukraine. This is due to dynamic changes in the information and educational environment, the introduction of the NUS (New Ukrainian School) Concept, the search for effective methods of learning information, the formation of a new «portrait» of a generation of schoolchildren, etc.

The analysis of literature sources (Moroz, et al., 2006; Stepanyuk, 1999) and our own teaching experience have shown that visualization techniques in the educational process in natural sciences have historical roots. Thus, visualization in the educational process in the definition of «visual aids» has been present since the time of J. Comenius and is associated with his «golden rule» of didactics. It is worth recalling the unique methodological advice of the prominent biologist M. Verzilin on drawing on the blackboard. The teacher noted that schematic drawings that explain the essence of a biological phenomenon or model are very important in teaching biology. Also, students should be taught to draw from nature, not to copy the teacher's drawings (Moroz, et al., 2006). However, the objective factors of the modern educational process at all levels of education have changed so significantly that the didactic aspects of visualization require a rethinking and a systematic approach to the study of its educational effect.

The interpretation of the modern semantics of visualization in the educational process in the field of pedagogy is ambiguous. In a general sense, visualization (from Latin visualis- visual) is a method of converting a radiation field invisible to the human eye into a visible image of a radiating object. In the Modern Explanatory Dictionary of the Ukrainian Language, visualization is defined as «obtaining a visible image of some objects, phenomena or processes that are not available for physical observation» (Suchasnyi tlumachnyi slovnyk, 2009, p. 149).

The terminological analysis of the concepts of visual education is carried out by M. Drushliak (2018). N. Biloshapka (2021) interprets visualization as a leading idea of the modern educational process in the context of the world's informatization. Visualization as a modern learning strategy is analyzed by D. Bezuglyi (2014). The use of visualization technologies to intensify the learning process was the subject of scientific research by L. Bilousova & N. Zhyteniova (2017). Scientists (Zhytienova, 2016) have also studied the peculiarities of the thinking of the modern digital generation, the possibilities of modern educational trends for their use in the educational process for

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visualizing information. N. Honcharova (2021) is developing the issue of educational information visualization through the use of augmented reality technology. An interesting technology of creative coding of information in the process of studying humanities is suggested by I. Hrynenko (2006) – organization of sign and symbolic activity. An innovative method of using schematic drawings to explain the essence of a biological phenomenon, processes or their models was suggested by G. Yagenska (2019).

As our research has established (Kartashova & Stepanyuk, 2022), the methodological basis of visualization technology is the principle of system quantization and the principle of cognitive visualization. The essence of the technology of educational material visualization is: the unity of methodological techniques for incorporating visual models into the educational process; systematic use of visual models of the same type or their combination; teaching students to rationally process information and its cognitive and graphical representation.

The didactic possibilities of using structural and logical terminological schemes to visualize educational material during the perception of information, its comprehension, awareness, consolidation, application and generalization in the process of professional training of future bachelors of biology have been determined by the research of I. Upatova, O. Dekhtyariova & L. Prokopenko (2021) as well as in our research (Stepanyuk & Kartashova, 2023). The essence of structural and logical schemes for describing types of knowledge as a means of cognitive knowledge visualization and the possibility of their use in the process of future natural sciences teachers professional training have been revealed in our research (Kartashova & Stepanyuk, 2022).

O. Silkova and N. Lobach (2017) state that scientists distinguish between two functions of visualization: illustrative and cognitive. The illustrative function allows us to embody in a relatively adequate visual design only that, which is already known, that is, what already exists. The cognitive function is to obtain new knowledge with the help of a certain image, to promote the intellectualization of the process of obtaining new knowledge.

In our opinion, these functions are the basis for distinguishing between traditional and innovative approaches to visualization, which differ in methods, tools, and purpose. Traditional approaches consider the result of visualization as an illustration, which does not involve the development of cognitive skills and requires students' learning activities at the reproductive level. They focus on the use of time-tested methods and tools to convey information. Their main features are: static (visualization is traditionally presented in the form of static images, such as drawings, diagrams, graphs and charts); simplicity (traditional methods involve presenting information in a way that facilitates easy understanding but limits in-depth analysis; use of visual aids (whiteboards, printed materials, maps and atlases); minimal interactivity (students or learners perceive information passively, without the ability to influence its presentation). For example, handwritten diagrams and drawings on the board, printed graphs in textbooks, tables, charts, etc. The advantages of this approach are as follows: easy to create and use; easy to learn basic concepts; effective for small amounts of information. Among the disadvantages are limited interactivity and the possibility of in-depth analysis, and difficulty in displaying dynamic processes.

Innovative approaches to visualization mean involving students in collaborative activities in which the student is the subject of educational and cognitive activity. They are based on the use of modern technologies that expand opportunities for interactivity, dynamics and personalization. For example: interactive data panels (dashboards); 3D visualizations; animated infographics; virtual and augmented reality; simulations and models, etc. The advantages of these approaches are as follows: increased motivation and engagement in activities; the possibility of personalized training; effective presentation of complex and dynamic processes. The disadvantages include the high cost of implementation, the need for technical training of teachers and students, and the need for technological resources.

Both approaches to visualization have their advantages and disadvantages and can be used depending on the learning situation. Traditional methods are convenient for explaining basic concepts, while innovative approaches provide deeper analysis and engagement. In today's world their combination is the best option to ensure effective learning. This conclusion was taken into account by us when designing an experimental methodology for implementing the scribing method.

In our study, we are of the same opinion as O. Seminikhina and M. Drushliak (2017), who consider that visualization is inherent in cognitive function. Including visualization in the learning process not only «helps» the learner to organize mental activity at the stage of perception of educational information, but also forms meaningful knowledge, influencing the awareness of the information received in a special way of its presentation.

In recent years, there has been a proliferation of scientific publications on exploring the potential use of visualization techniques in the educational process during biology studying. In particular, researchers Erwinsah, R., Aria, M., & Yusup, Y. (2019) have investigated the issue of application of augmented reality technology in biological learning. Researchers Fuchsova, M., & Korenova, L. (2019) have focused their studies on the issue of visualisation in science and engineering education of future primary school teachers in human biology education using augmented reality.

Scientists Celik, C., Guven, G. & Cakir, N. K. (2020) proposed applying integration of mobile augmented reality applications into biology laboratory. Ciloglu, T. & Ustun, A. (2023) investigated the effects of mobile AR-

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based biology learning experience on students' motivation, self-efficacy, and their attitudes to online biology learning. Dehghani, M., Mohammadhasani, N., Hoseinzade Ghalevandi, M. & Azimi, E. (2023) studied the issue of applying AR-based infographics to enhance learning of the heart and cardiac cycle in biology class.

Stepanyuk, A. V., Mironets, L. P., Olendr, T. M., Tsidylo, I. M. & Stoliar, O. B. (2020). suggested methodology of using mobile Internet devices in the process of biology school course studying. And the scientific work of Verdes, A., Navarro, C., & Álvarez-Campos, P. (2021) substantiated the significance of mobile learning applications to improve invertebrate zoology online teaching. Research by Gregorcic, T. & Torkar, G. (2022) found that using the structure-behavior-function model in conjunction with augmented reality helps students understand the complexity of the circulatory system.

Ihsan, M., Sa'adah, S. & Maspupah, M. (2023) studied the issue of the validity of markerless augmented reality-based learning media on the concept of cell organelle. Irschick, D. J., Christiansen, F., Hammerschlag, N., Martin, J., Madsen, P. T., Wyneken, J., Brooks, A., Gleiss, A., Fossette, S., Siler, C., Gamble, T., Fish, F., Siebert, U., Patel, J., Xu, Z., Kalogerakis, E., Medina, J., Mukherji, A., Mandica, M. & Lauder, G. (2022) studied 3D visualization processes for recreating and studying organismal form.

Kumar, A., Saudagar, A. K. J., Alkhathami, M., Alsamani, B., Khan, M. B., Hasanat, M. H. A., Ahmed, Z. H., Kumar, A. & Srinivasan, B. (2023) substantiated the opportunities of gamified learning and assessment using ARCS with next-generation AIoMT integrated 3D animation and virtual reality simulation. López-Cortés, F., Moreno, E. R., Palmas-Rojas, C. & Rubilar, C. M. (2021) studied secondary education students' levels of external representation of mitotic cellular division based on augmented reality.

Nurhayati, Rusdi & Isfaeni, H. (2022) contributed to the development of the issue of application of mobile augmented reality to improve learning outcomes in senior high schools. Petrov, P. D. & Atanasova, T. V. (2020) studied the effect of augmented reality on students' learning performance in STEM education. Reeves, L. E., Bolton, E., Bulpitt, M., Scott, A., Tomey, I., Gates, M. & Baldock, R. A. (2021) considered the issue of the use of augmented reality (AR) to aid bioscience education and enrich student experience. Additionally, Garcia-Bonete, M. J., Jensen, M. & Katona, G. (2019) created a practical guide to developing virtual and augmented reality exercises for teaching structural biology. And Arslan, R., Kofoğlu, M. & Dargut, C. (2020) developed an augmented reality application for biology education.

Generalizing the contribution of scholars, we came to the conclusion that knowledge visualization is the process of transforming abstract information, data, or ideas into visible forms, such as diagrams, mind maps, or schemes. Its main objective is to make knowledge accessible and understandable, fostering easier acquisition of knowledge. Thanks to visualization, information becomes not only more attractive for perception, but also acquires new connections and meanings, which contributes to a deeper understanding of the educational information. That is, in modern education, it is becoming not only a way of presenting material, but also a key element of cognitive development (critical thinking, analysis, synthesis, generalization of information, etc.). It is achieved by graphically displaying complex concepts, the interrelations among them and their place in in the overall knowledge system.

Presentation of the main material. The methodology adopted for this study includes a theoretical analysis of the issue, study of the practice of its solution, modeling of the methodology of conducting an experimental study among students and teachers from different regions of Ukraine (Ternopil, Sumy and Kherson regions). Data collection was carried out using the methods of questionnaires, conversations, expert evaluation, ranking, diagnostic work.

To achieve the aforementioned goal, several theoretical methods have been employed, including theoretical – comparative analysis to explore different perspectives on the problem and identify areas of study, modeling to develop the methodology of the forming experiment, constructing to develop the content of classes and criteria for research, and systematization and generalization to formulate conclusions. Additionally, the following empirical methods were used: generalization of pedagogical experience, scientific observation, interviews, content analysis, and questionnaires to evaluate the state of the issue implementation in practice and develop the content of the experimental teaching methodology. The effectiveness of the suggested methodology was verified through a pedagogical experiment, which involved expert evaluation of the developed experimental materials.

The experimental research was conducted at Ternopil V. Hnatiuk National Pedagogical University, Kherson State University and Sumy A. Makarenko State Pedagogical University. The effectiveness of the proposed methodology was evaluated during a two-year period spanning the 2023-2024 and 2024-2025 academic years. The research involved 21 lecturers from higher education institutions and 108 teachers from secondary schools of Ukraine. 60 students at the second (master's) level of the educational and professional program in Secondary Education (Natural sciences) and 216 schoolchildren were involved in the forming experiment.

The methodology of the experimental research encompassed several stages:

– the preparatory stage, which involved the analysis of knowledge visualization techniques, expert evaluation of their quality according to the criterion of «didactic quality» and certain indicators (Table 1);

– the organizational and methodological stage, where ranking of the selected visualization techniques was

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carried out and the experts' preferred technique, namely scribbling was identified. The pedagogical conditions for the effective use of scribbling techniques were determined. A methodology for conducting a formative experiment was developed;

– the procedural stage, which involved the formative experiment conducting;

– the reflexive-analytical stage, where the results of the experimental training were analyzed based on certain indicators (completeness and awareness of knowledge; of formation the ability to compare).

To evaluate the effectiveness of the application of the described knowledge visualization techniques, we used the integral criterion of 'didactic quality', which was determined by the method of expert evaluation. We were prompted to choose it by taking into account the following provisions of the theory of educational content formation: «it is necessary to evaluate the effectiveness and validity of new ideas, methods and provisions first of all theoretically; the centuries-old experience of constructing the content of the basic sciences... shows that the main method in the selection of material is the expert method, namely, the opinions of scientists and specialists» (Stepanyuk, 1999, p. 326).

A group of experts consisting of scientists and lecturers from pedagogical higher education institutions across Ukraine was formed to conduct the research. The composition of the expert group intentionally varied. This allows us to consider a wide range of opinions regarding the alignment of the proposed content with the needs, real conditions of teaching practice, and the current state of knowledge visualization issue. The experts exhibited high levels of competence, i.e. they possessed necessary knowledge to create their own model of the issue under consideration on the basis of the received information, to synthesize extraordinary conclusions, and their field of activity, specialization and scientific interests refer to the same field as the issue under analysis. 2. Interest in the examination results. 3. A businesslike character. 4. Objectivity and impartiality.

A group of 21 competent specialists in the field of the studied problem was selected. This group comprised teachers of natural sciences and methods of teaching them with more than 10 years of degree and teaching experience. This group of experts agreed upon the indicators according to which the described techniques were to be assessed. The results are presented in Table 1.

The examination was carried out in April 2023. The quality of the proposed technologies was assessed by the integral indicator of their «didactic quality», as well as on the basis of «multi-factor ranking». The criterion of «didactic quality» was determined as the total degree of compliance of each lesson submitted for examination with the set of indicators put forward.

Subsequently, each expert individually completed a questionnaire assessing a set of factors. The questionnaires were then studied and analyzed. The experts' scores were processed using statistical methods based on the assumption that an expert can be considered as a measuring device whose indicators have random and systematic errors. Based on the results of the examination, the rating of visualization techniques was determined by ranking.

The experimental study to test the effectiveness of the pedagogical conditions for using scribbling technology in the process of studying biology was conducted in two stages. The purpose of the first stage was to test the impact of this technology on the quality of learning. With this aim, we tested such indicators of the quality of fully acquired knowledge as completeness and awareness.

In order to substantiate the feasibility of using the technology of visualization of educational information during the study of natural sciences subjects in general secondary education institutions and future natural sciences teachers professional training, we conducted a local experiment on the use of scribing technique in the educational process. It took first place in our ranking. Two groups of students were selected: experimental (E) and control (C). In the E group, lessons were conducted using the technique under study, and in the C group, the same topic was taught using the traditional method. Immediately after the lecture, the quality of the knowledge acquired by the students was tested. Such indicators of knowledge quality as completeness and awareness were checked.

The results of testing the effectiveness of the proposed visualization technique, reflected in the change in the quality of knowledge of students from E and C groups, are presented in Table 2.

The purpose of the second stage of experimental study was to test the effectiveness of the suggested methodology of using the technology of knowledge visualization, which took into account the three identified pedagogical conditions in a complex. For this purpose, we selected three groups of respondents: control (C), experimental^1 (E^1) and experimental^2 (E^2). In the C group, classes were conducted using only traditional means of knowledge visualization: drawings, diagrams, charts, etc. In the E^1 group, the same educational material was studied using both traditional and innovative visualization techniques only at the stage of perception, clarification, and expansion of information. These techniques were aimed at a holistic reflection of the object of study in its natural environment and the coordinated functioning of the left and right hemispheres of the student's brain. In the E^2 group, the training was conducted according to the author's methodology, which provided for the consideration of certain pedagogical conditions at all stages of the lesson, taking into account the principle of expediency.

Since any problem arises from practice, we conducted a survey of teachers in Ternopil, Kherson and Sumy

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regions as for their use of educational information visualization technology. The results of the survey of 108 respondents allowed us to state that the majority of teachers use the visualization method in their educational activities, as 72 of them (66.7%) answered «yes, always», 28 (25.9%) – «rarely» and only 8 (7.4%) – «no, never».

The analysis of 100 teachers' answers revealed that answering the second question (What visualization methods do you use?) the following visualization methods were employed: diagrams (80.0%), graphs (60.0%), Internet memes (48.0%), and lapbooks (40.0%). The third question of the questionnaire (What visualization method do you use most often?) was answered by 88 respondents. The results show that teachers most often use diagrams in their professional activities (22.7%), lapbooks (18.2%), Internet memes (13.6%), and diagrams (13.6%). Since only two respondents (4.5% each) mentioned the use of scribing, graphs, and online books as methods of knowledge visualization, it can be concluded that teachers are not familiar with these types of knowledge visualization or consider them ineffective.

The answers of 80 respondents to the fourth question showed that the majority of teachers (36 persons, 45%) use visualization methods when teaching new material, a slightly smaller part of them (28 persons, 35%) consider it appropriate to use these methods at such a stage of the lesson as consolidation and systematization of knowledge, and 20 teachers (25%) - when summarizing knowledge. We found it interesting that 20 % of respondents practice using knowledge visualization methods at the stage of updating basic knowledge. The answers of the respondents to the last question are reassuring, according to which almost all respondents consider it appropriate to specially train future teachers in visualization methods in the course of their professional training (96%). Thus, the teachers share our opinion that it is necessary to conduct targeted training of future natural sciences teachers to implement cognitive visualization of the educational process. Consequently, teachers consider «timeline» and «intelligence map» to be the most commonly used knowledge visualization techniques.

In accordance with the objectives of our study, we will analyze the existing visualization techniques as components of the technology of educational information visualization, taking into account the specifics of the content of the natural sciences disciplines during the training of future natural sciences teachers.

Based on the analysis of literature sources (Holubchak, & Kostiuk, 2019; Kokhan, 2013; Merdukh, Tolokonnikova & Vasylkiv, 2020; Mykytiv, 2020; Mykytiv, 2020; Silkova, & Lobach, 2018; Zhytienova, 2016; Onofriichuk, 2020), it can be concluded that there are a considerable number of modern techniques for visualizing educational information. Most of them are based on the idea that the subject's perception of the object of study is more effective the more it is accompanied by the active activity of the learner. We will describe the most commonly used ones in the educational process:

1. *Timeline* (English –a line of time) is a straight line on which events are plotted in chronological order. It is advisable to use this technique when depicting a line or ribbon of time when working with biographies of scientists, as well as to form students' systematic view on the historical processes of the living world. It is also used in the management of educational projects. The timeline helps participants mark and see the stages of project implementation and deadlines.

2. *Intelligence map* (mental map, relationship diagram, mind map, associative map, mind map) is a graphical way of depicting the process of systemic thinking using diagrams, which is used to create, visualize, structure ideas, and it is also a learning tool. It is used in the educational process to: visualize educational materials; quickly process large amounts of information; memorize basic terms and concepts; develop students' associative thinking; create clear notes; solve creative problems; plan and develop educational projects, etc.

3. *Scribbling* (English «scribe» - to sketch or draw) is the visualization of information using graphic symbols that simply and clearly reflect its content and internal connections (British artist Andrew Park). The use of the scribbling technique is primarily the art of accompanying oral speech «on the fly» with drawings with a felt-tip pen on a white board (or sheet of paper). As a rule, the key points of the story and the relationship between them are illustrated. The creation of vivid images evokes listener's visual associations together with oral speech, which ensures a high percentage of information assimilation.

The most commonly used scribbling techniques are the following: Painted, which is a classic version of scribbling. The artist's (scribe's) hand draws pictures, icons, diagrams, charts, and keywords in the frame simultaneously with the text that sounds off-screen. To ensure that voice acting and drawing coincide perfectly in time, the drawing process is accelerated by 2-4 times during the video creation, titles are also added, and editing is done; Application means that ready-made images are laid out (glued) on a sheet of paper or any other background in the frame to match the text that sounds off-screen; Magnetic is similar to application, the only difference is that the finished images are attached to the presentation magnetic board with magnets; Computer is a technique when special programs and online services are used to create computer scribbling. The simplest version can be created using Power Point.

During a cartoon presentation, the images on the slides appear gradually, in accordance with the narration «off-screen». In this case, the basic principle of scribbling is followed, the «parallel passage effect».

There are the following types of scribbling: scribe presentation is the use of cloud services; scribe facilitation

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is the translation of information from verbal to visual form and its recording in real time, accompanying the story with schematic drawings; video scribbling is a short video accompanied by schematic drawings.

4. *Crossence* (English «cross» - intersection, «sens» - meaning, so crossence is the intersection of meanings, concepts) is a new generation associative puzzle, a visual associative chain consisting of 9 images. The images are arranged in such a way that each picture has a connection with the previous and the next ones. The central picture combines several pictures in terms of meaning. (The idea belongs to the writer, teacher and mathematician S. Fedin and the doctor of pedagogical sciences, philosopher and artist V. Buslenko). The task of the person solving the crossword puzzle is to find an associative connection between adjacent (i.e., those that share a common side) pictures. The connections in the puzzle can be both superficial and deep.

Crossence is a modern methodological technique of educational material visualizing that performs the following functions: educational (promotes learning); motivational (provides interest in the topic); communicative (creates micro- and macro-dialogues between participants of the educational process); social (explains the causes and patterns of a particular phenomenon, its elements of information, contradictions, etc).

5. *Infographics or information graphics* is a graphical visual representation of information, data or knowledge intended to present complex information quickly and clearly.

The main difference from other techniques is its metaphorical nature; it is not just a graph or diagram, but supplemented with visual natural information and analogies from life. The process of creating infographics can be seen as data visualization, creation of information schemes and models of information presentation. A perfectly executed infographics is a complete information unit that can be learned independently and very effectively.

The expediency of use during natural sciences teaching: informing about a scientific problem, natural phenomena, processes, facts and concepts, theories, patterns; improving the perception of a large amount of information using graphic materials to increase the ability of the human visual system to see patterns and trends.

The following types of infographics are used: statistical (a single slide without animated elements); interactive (video infographics, animated images). Effective types of infographics: numbers in pictures; detailed list; process and perspective. Practice shows that there are two main approaches to working with infographics: «teacher-student» which is used to draw attention to the topic; «student-teacher» is for independent creation of infographics by a student.

6. *Tag cloud* (word cloud, weighted list, visually presented) is a visual representation of a list of categories (or tags, also called labels, shortcuts). The importance of each keyword is indicated by the font size or colour. This view is convenient for quick perception and distribution of terms by popularity. The ready-made tag cloud can be offered to students or they can create their own for the topic, use it as a reference note and during formative assessment.

7. *Book trailer* is a short video based on a book; a video annotation of a book; a video thumbnail, a teaser, which demonstrates the most vivid and famous moments of a book. The following types of book trailers are used in the educational process: by the way the text is visually represented (fiction (mini-films), non-fiction (a set of slides with quotes, illustrations, photos), animation; by the content: narrative, atmospheric (conveying the mood of the book and the expected emotions), conceptual (conveying the main ideas and the general semantic orientation of the text). The purpose of the technique is to promote reading, to draw attention to popular science books with the help of visuals typical of movie trailers. It is possible to use both ready-made videos and encourage students to create them on their own during the educational process.

The described visualization techniques were analyzed and evaluated by a group of experts according to the indicators presented in Table 1.

Table 1

The weight of indicators of visualization techniques didactic quality

№	Indicators	Weight
1.	Possibility of application on the basis of the existing material and technical support of the information educational environment of the HEI	5
2.	Significance for creating a positive emotional background for teaching	20
3.	Significance for the organization of interactive pedagogical cooperation of the educational process participants	25
4.	Accessibility for perception learning information	20
5.	Expediency of use during future natural sciences teachers' professional training	20
6.	Easy to use for teachers and students	10

Source. Own research

The interviews with the experts showed that the proposed visualization techniques are overall accessible to scientific and pedagogical workers and important for enhancing their professional competence, as well as the possibility and expediency of their inclusion in the cognitive component of the future natural sciences teachers' professional and methodological training. The highest rating was given to the «scribbling» technique, then goes «intelligence map», «infographics», «timeline», «tag cloud» (only the top five positions were taken into account).

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The results of testing the effectiveness of the proposed visualization technique, reflected in the change of respondents' knowledge quality of control groups (C) and experimental groups (E), are presented in Table 2.

Table 2

Results of testing the respondents' knowledge quality

Knowledge quality indicators	**RResponse groups**	**Number of respondents whose responses correspond to the selected groups**							
		Control groups (C)				**Experimental groups (E)**			
		Amount of students (30 n)		**Amount of pupils (30 n)**		**Amount of students (30 n)**		**Amount of pupils (30 n)**	
		number	%	number	%	number	%	number	%
completeness*	I	15	50.0	16	53.3	18	60.0	20	66.7
	II	7	23,3	7	23.3	8	26.7	7	23.3
	III	8	26,7	7	23.3	4	13.3	3	10.0
Aawareness**	I	14	53,4	14	46.7	20	66.7	22	73.4
	II	8	23,3	9	30.0	6	20.0	7	23.3
	III	8	23,3	7	23.3	4	13.3	1	3.3

** I – correct complete answer; II – correct incomplete answer; III – no correct answer*

*** I – correct answer; II – incorrect answer; III – no answer; n – number of respondents*

Source. Own research

The results of testing students' knowledge by the indicator of «completeness of knowledge» showed that the students from E group demonstrated better knowledge acquisition. 60.0 % of students in this group gave correct complete answers. Only 50.0% of students gave such answers in C group. 13.3 % of respondents in E group and 26.7 % in C group did not answer the question. As a result of conducting a lesson using the scribbling technique, there was an increase in the number of students whose knowledge completeness corresponds to the first level from 50.0% to 60.0% (+10%), the second level from 23.3% to 26.7% (+3.4%), and a decrease in the third level from 26.7% to 13.3% (–13.4%).

Among schoolchildren, there was an increase in the number of responses according to the «knowledge completeness» indicator corresponding to the first level by 13.4% (from 53.3% to 66.7%). There were no changes at the second level. We noticed the decrease in the number of answers at the third level from 23.3% to 10.0% (-13.3%).

We obtained similar results for the «knowledge awareness» indicator. The students in E group are more aware of the knowledge they have acquired than those in C group. Correct answers were given by 66.7 % and 53.4 % of students, respectively. 23.3% respondents of C group and only 13.3 % respondents of E group do not realize the difference in the ways of acquiring knowledge and the means of its substantiating (the indicator «knowledge awareness»). The students of E group showed an increase in the number of responses corresponding to the first level by 20.0%, while at the second and third levels, they demonstrated a decrease (by 3.3% and 10%, respectively). Among schoolchildren, these results were higher: +24.7%, –6.7%, and –20.3%, respectively.

We arrived at the conclusion that schoolchildren at secondary schools perceive the use of the scribbling technique better than university students by comparing the indicators of knowledge quality acquisition (completeness and awareness). We can explain this by their more well-formed clip thinking. Therefore, we conducted the second series of the experimental study on schoolchildren.

Based on the theoretical analysis of the issue we singled out pedagogical conditions of the effective use of scribbling technique in the educational process during biology studying, namely:

1. The best option for ensuring quality learning of natural sciences material is a combination of traditional and innovative approaches to knowledge visualization.

2. The organization of the qualitative educational process for the study of wildlife objects needs construction of the scientific and methodological support based on the consideration of illustrative and cognitive functions of visualization in the complex.

3. It is advisable to use educational material visualization at all stages of classes: checking homework, motivation of learning and cognitive activity, actualization of basic knowledge, perceiving information, clarifying and expanding, reproducing educational material and summarizing.

To evaluate the effectiveness of the suggested pedagogical conditions for implementing scribbling technology (the second stage of the experimental study), we created our own methodology for studying the school biology course. Its main essential characteristics are the following: in the process of studying the educational material, the scribbling technique is used while combining traditional and innovative approaches to knowledge visualization; the study of wildlife objects was based on both illustrative and cognitive visualization; scribbling techniques were used at all stages of classes, taking into account the principle of expediency.

The authors' methodology involved the use of the following main categories of software that are useful for studying nature:

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1. Simulations and visualizations of natural phenomena:

- PhET Interactive Simulations – interactive simulations of physical, chemical and biological processes (https://phet.colorado.edu/uk/).
- Stellarium – virtual planetarium for studying astronomy (https://stellarium.org/uk/).
- Celestia – software for 3D space modeling (https://celestiaproject.space/).
- Algodoo – program for modeling physical phenomena in a two-dimensional environment (https://www.algodoo.com/).

2. Virtual laboratories:

- Labster - virtual laboratory experiments in biology, chemistry and physics (https://www.labster.com/).
- ChemCollective – interactive experiments in chemistry (https://chemcollective.org/).

3. Educational platforms and interactive courses:

- Khan Academy - courses in physics, chemistry, biology and ecology (https://uk.khanacademy.org/science).
- Coursera, EdX, Prometheus – online courses from leading universities (https://prometheus.org.ua/coursera/).
- Google Earth – for studying geographical and ecological processes (https://www.google.com.ua/earth/).

There are some examples of tasks for studying the theme «Birds» in grade 7, the solution of which involved the use of scribbling techniques. The most appropriate stages of the lesson for their use in the experimental methodology are indicated. Namely:

- *Actualization of basic knowledge and skills*. (1. Create a crossence «Life of Birds» or «Birdsong». 2. Using application scribbling, make up a story about the internal structure of a bird. 3. Make a comparative analysis of the circulatory system of birds and reptiles in the form of a table.)
- *Motivation of students' learning and cognitive activity.* (1. Model an artificial bird's nest from natural materials (grass, branches, feathers) to confirm your own hypothesis about how birds choose materials for nest building. 2. Using the bricolage technique, make three-dimensional models of the beak and free lower limbs of a fantastic bird that lives only in tall trees from improvised materials (paper, fabric, wood, plasticine, etc.). 3. Make a story based on the crossence «Structure of birds». 4. Watch the video «Feathered record holders of Ukraine» on YouTube in the series «Wildlife», think about what features in the external structure of birds allow them to be record holders in flight).
- *Learning of new material*. (1. Create a timeline identifying the surnames of environmental scientists and themes of their scientific researches as the teacher tells the story of the history of investigating animal behaviour by scientists. 2. Make a model out of plastic bottles or cardboard (bricolage technique) to demonstrate the aerodynamics of bird wings. 3. Create a Statistical Infographic to visualize the classification of birds (the «Bird Tree»). 4. Create a Versus or Comparison Infographic to show the differences between ecological groups of birds. 5. Use scribe facilitation to work on the topic «Flight adaptations of birds»).
- *Consolidation of the acquired knowledge.* (Make an intelligence map on the topic «Adaptability of birds to flight»)
- *Home assignments* (1. Create a collage using natural materials that shows the map of birds' migration. 2. Demonstrate camouflage phenomenon in coloring of birds' feathers using a mosaic of leaves, seeds, twigs. 3. Analyze Table 4 and draw a graph showing the relationship between the respiratory rate of birds and their body length, and a graph showing the relationship between the heart rate of birds and their body length.

Table 3

Objective data of birds

Bird	**Body length, cm**	**Heart rate (resting), per minute**	**Respiratory rate (resting), per minute**
House sparrow	14	350	60
Chicken	40	250	30
Steppe eagle	70	100	20
Hummingbird	6	600	250

Source. ChatGPT

In the process of testing the effectiveness of the authors' methodology of applying scribbling technology in biology studying, the levels of students' ability to make comparisons (D^1) were diagnosed in grades 10-11 at the beginning of the formative experiment. Its results are presented in Table 4. The diagnostic assessment showed that at the beginning of the experiment the quantitative indicator for each level in the control and experimental groups was approximately the same. This indicates equal conditions at the beginning of the experiment.

The analysis of the results after the formative experiment showed that both in control and experimental

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groups changes took place at each level of comparison skills formation. A comparative analysis of the diagnostic assessments (D^1 and D^2) conducted at the beginning and after the completion of the formative experiment allowed us to identify the dynamics of the development of comparison skills. The results of the comparative analysis are presented in Table 4 and Figures 1, 2, 3.

Table 4

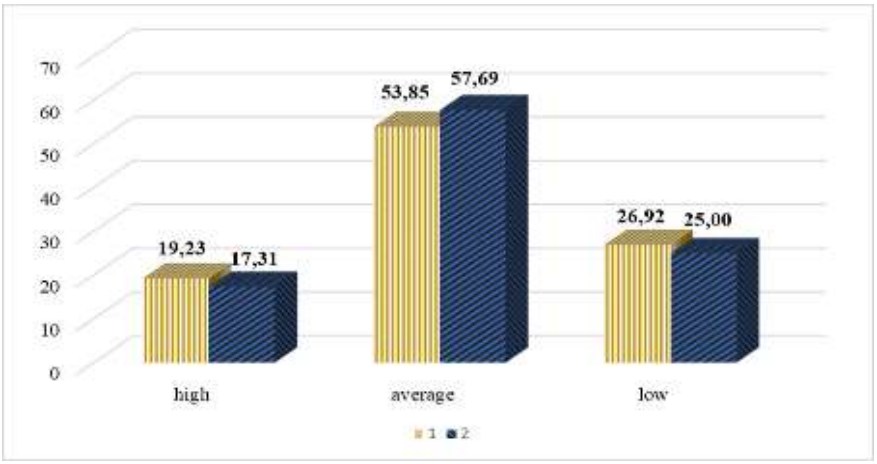
Dynamics of the levels of formation of the ability to compare

Levels*	Control group (52 n)				Experimental groups (104 n)							
					E^1(52 n)				E^2(52 n)			
	D^1		D^2		D^1		D^2		D^1		D^2	
	n	%	n	%	n	%	n	%	n	%	n	%
I	10	19,23	9	17,31	9	17,31	11	21,15	10	19,23	16	30,77
II	28	53,85	30	57,69	29	55,77	32	61,54	26	50,00	33	63,46
III	14	26,92	13	25	14	26,92	9	17,31	16	30,77	3	5,77
F-criterion	1,09				1,13				1,61			

**I – high level; II – average level; III – low level*
D – diagnostic assessments
Source. Own research

Based on the analysis of the data in Table 4, we can state that schoolchildren in the C group exhibited minor changes due to the influence of the traditional methodology of natural sciences studying and overall personal development. However, they did not reach the level of statistical significance. The dynamics of the levels of formation the ability to compare in the control group is graphically presented in Figure 1.

In the control group, minor positive changes occurred in the indicators of average level of formation the ability to compare, increasing from 53.85% to 57.69%. The number of schoolchildren with a high level changed from 19.23% to 17.31% and with a low level from 26.92% to 25.00%.



1 – before the formative experiment; 2 – after the formative experiment
Source. Own research
Figure 1. Change in the level of formation of the ability to compare of the schoolchildren in C group

Comparison of the results of the formative experiment revealed quantitative changes in the levels of formation of the ability to compare in both E^1 and E^2 groups. The dynamics of the levels of formation of the ability to compare of schoolchildren from E^1 and E^2 groups is graphically presented in Fig. 2 and Fig. 3. Thus, in E^1 group, the number of schoolchildren with a high (from 17.31% to 21.15%) and an average (from 55.77% to 61.54%) level of formation of the ability to compare increased. The number of schoolchildren with a low level decreased from 26.92% to 17.31%.

However, significant statistically reliable differences in numerical indicators were observed in the E^2 group. They are characterized by greater quantitative changes. The number of schoolchildren with a low level of formation of the ability to compare has significantly decreased (from 30.77% to 5.77%). The indicators of high (from 19.23% to 30.77%) and average (from 50.00 to 63.46%) levels of formation of the ability to compare increased.

To prove the reliability of the results of our study, we used the F-criterion (Kyverialh A., 1980, pp. 276-280). In the C group, it was 1.09, in the E^1 - 1.13, in E^2 - 1.67. Thus, on the basis of these data, we can conclude that as a result of the application of a holistic methodology, which takes into account the pedagogical conditions for the effective use of scribble techniques which were determined by us, schoolchildren demonstrate an effective formation of a high level of the ability to compare.

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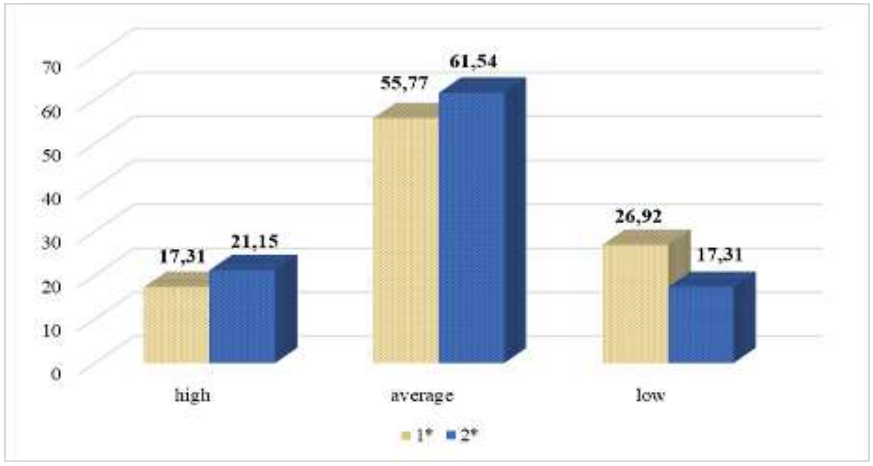
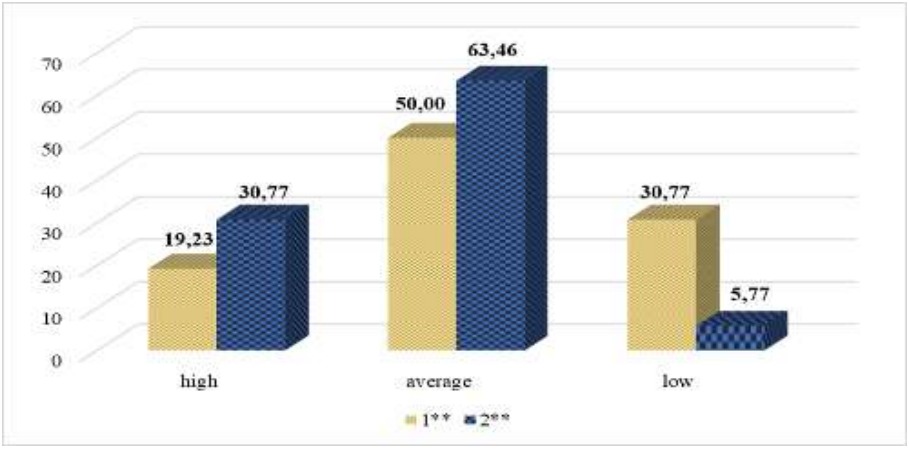


1* - before the formative experiment; 2* - after the formative experiment
Source. Own research

Figure 2. Change in the level of formation of the ability to compare of the schoolchildren in E^1 group



1** - before the formative experiment; 2** - after the formative experiment
Source. Own research

Figure 3. Change in the level of formation of the ability to compare of the schoolchildren in E2 group

Conclusions. The didactic possibilities of visualization are quite wide: it helps students to rationally organize and analyze information; promotes the assimilation of a large amount of information; develops critical thinking; promotes the integration of knowledge; allows you to link the information received into a holistic picture of a particular object, phenomenon, process.

The most widely spread and effective in the educational process of natural sciences studying in Ukraine are the following knowledge visualization techniques: scribbling technique, intelligence map, infographics, timeline, tag cloud.

The pedagogical conditions of the effective use of scribbling technique in the process of natural sciences studying are as follows:

1. The best option for ensuring quality learning of natural sciences material is a combination of traditional and innovative approaches to knowledge visualization.

2. The organization of the qualitative educational process for the study of wildlife objects needs construction of the scientific and methodological support based on the consideration of illustrative and cognitive functions of visualization in the complex.

3. It is advisable to use educational material visualization at all stages of classes: checking homework, motivation of learning and cognitive activity, actualization of basic knowledge, perceiving information, clarifying and expanding, reproducing educational material and summarizing.

The analysis of the results of the formative experiment gives grounds to conclude that the use of scribbling technique as a means of knowledge visualization in the process of natural sciences courses studying at school and in the process of future natural sciences teachers training for professional activity is effective. The introduction of visualization technology contributes to improving the quality of educational services, the formation of a holistic perception of the environment that combines logical as well as visual and imaginative thinking.

The educational process with the use of knowledge visualization technology provides a holistic approach to the perception of information, which involves the activation of various senses, coordinated interaction of the left and

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right hemispheres of the brain; encourages independent work of each student; creates a favourable communication situation and conditions for the development of creative abilities of the individual; increases the motivation and cognitive activity of students; improves individualization, differentiation and intensification of the educational process; expands and deepens interdisciplinary.

Moving forward, there are promising prospects for studying the impact of the use of knowledge visualization technology on the formation of knowledge quality indicators, soft skills and hard skills of students of different levels; integrated training of future natural sciences teachers to model educational activities using knowledge visualization technology.

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ВІЗУАЛІЗАЦІЯ ЗНАНЬ ШКОЛЯРІВ ЯК ІНСТРУМЕНТ ДЛЯ РОЗВИТКУ КОГНІТИВНИХ НАВИЧОК У СУЧАСНІЙ ПРИРОДНИЧО-НАУКОВІЙ ОСВІТІ

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Вступ. *Наш час характеризується надзвичайною мінливістю та невизначеністю в умовах як природних, так і соціальних процесів. Серед суттєвих характеристик сучасного освітнього процесу в Україні – розвиток інформаційних технологій, сприйняття інтернету як невід'ємної частини нашого життя, активне впровадження змішаного навчання, інновації в галузі передачі інформації, засновані на механізмах візуального сприйняття інформації та візуально-образного мислення. Усе це зумовило якісні зміни в розвитку освіти та суспільної свідомості її учнів.*

Мета. *Визначити та обґрунтувати найефективніші методи візуалізації для засвоєння змісту природничо-наукових предметів, а також професійно-методичну підготовку майбутніх учителів природничих наук на основі аналізу існуючих методів візуалізації та їх експертної оцінки.*

Методи. *Методологія, прийнята для цього дослідження, включає теоретичний аналіз проблеми, вивчення практики її вирішення, моделювання методології проведення експериментального дослідження серед учнів та вчителів з різних регіонів України. Збір даних здійснювався за допомогою методів анкетування, експертної оцінки, діагностичної роботи.*

Результати. *Встановлено, що використання методів візуалізації знань сприяє підвищенню якості hard skills учнів. Встановлено, що поєднання традиційних та інноваційних підходів до візуалізації є найкращим варіантом для забезпечення ефективного навчання. Визначено п'ять найефективніших методів візуалізації для забезпечення цілісного сприйняття знань через поєднання логічного та образного мислення. Окреслено та експериментально підтверджено педагогічні умови ефективного використання техніки малювання в процесі вивчення природничих наук.*

Експериментально обґрунтовано ефективність техніки малювання, її вплив на якість засвоєння знань та формування когнітивних навичок (на прикладі порівняння).

Оригінальність. *На основі аналізу існуючих методів візуалізації розглянуто підходи та найефективніші методи візуалізації для засвоєння змісту природничонаукових предметів, а також професійно-методичну підготовку майбутніх учителів природознавства, а також виявлено проблеми та суперечності в досліджуваній науковій галузі.*

Висновок. *Використання технології візуалізації знань забезпечує цілісний підхід до сприйняття інформації, що покращує якість освіти школярів.*

Ключові слова: *якість освіти, педагогічні умови, школярі, методи візуалізації, малювання.*

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ПЕДАГОГІЧНІ УМОВИ ФОРМУВАННЯ ЗДОРОВ'ЯЗБЕРЕЖУВАЛЬНОЇ КОМПЕТЕНТНОСТІ УЧНІВ ПОЧАТКОВИХ КЛАСІВ

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У статті здійснено всебічний аналіз особливостей формування здоров'язбережувальної компетентності учнів початкової школи та окреслено специфічні педагогічні умови, що забезпечують ефективність цього процесу. Розкрито зміст поняття «здоров'язбережувальна компетентність» у контексті сучасних освітніх вимог та акцентовано увагу на важливості раннього формування в учнів ціннісного ставлення до власного здоров'я. Окремо проаналізовано чинники, що впливають на збереження і зміцнення фізичного, психічного та соціального благополуччя дітей молодшого шкільного віку. Показано роль учителя, освітнього середовища та організації навчальної діяльності у створенні умов, сприятливих для гармонійного розвитку та формування корисних навичок здорового способу життя. У статті також розглянуто сучасні педагогічні технології, інтерактивні методи та форми роботи, які сприяють розвитку свідомого ставлення учнів до здоров'я, формуванню в них життєвих умінь і практичних навичок його збереження. Окреслено перспективи подальших досліджень і можливості вдосконалення здоров'язбережувального освітнього середовища в початковій школі.

Ключові слова: *здоров'я, здоров'язбережувальна компетентність, початкова школа, педагогічні умови, формування, особистість, освіта, розвиток, валеологічне виховання.*

Постановка проблеми у загальному вигляді. Проблема формування здоров'язбережувальної компетентності в учнів початкової школи є однією з ключових у сучасній педагогічній науці, адже вона безпосередньо пов'язана з якістю життя майбутнього покоління, його фізичним, психічним і духовним розвитком. У сучасних умовах зростає потреба у створенні такої освітньої системи, яка не лише передавала б знання, а й сприяла збереженню та зміцненню здоров'я дитини, формуванню в неї свідомого ставлення до власного способу життя.

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