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PEDAGOGICAL SYSTEM OF TEACHING NATURAL DISCIPLINES AT SCHOOL

Abstract. The concept of «system» implies the presence of a set of elements with relations and connections between them, which form a certain integrity. The article considers the learning process from the point of view of holistic education as a pedagogical system taking into account the components of problematycity, as a type of education that contributes to the development of students' creative abilities, and not a method of educational activity. System education leads to a property that individual elements do not possess. The statements of scientists regarding the components of the education system, which are not unambiguous, are given. The main attention is focused on the didactics of problem-based learning, the components of the educational environment remain less studied: the teacher and the student. Problem-based learning is a didactic system, as it offers a new structure of interaction between the teacher and students. The elements of the didactic system of problem-based learning include the organization of the content and structure of the learning process, the content and methods of learning, the construction of a system of methods of cognitive activity, the organization of content, forms and means of learning. But we adhere to the view that the didactic system of problem-based learning of the school course of natural subjects is built on a certain understanding of the logical and psychological patterns of the development of thinking and creative abilities of a person. Learning is based on learning by solving problems and has a developmental function in relation to the creative abilities of a person. This type of learning is a system for forming students' creative abilities, and not just a sum or an implicit set of individual methods for activating students' cognitive activity and thinking. The

author's model of the didactic system is depicted, in particular, the didactic system is a set of interconnected elements, which are the goals of learning, the content of learning, methods, means and organizational forms of learning, the system for assessing students' educational achievements. The characteristics of the component parts-elements of the system are given. The system-forming factor of the didactic system is two elements: learning goals and learning content. The internal connections between the elements of the system are emphasized in more detail on the principles of synergy and STEAM education. The developmental effect of problem-based learning, its advantages and disadvantages in the study of natural sciences are shown. Not all topics of the school course of natural sciences are expedient to study by the problem method.

Keywords: pedagogical system, problem-based learning, elements of the system, characteristics of the elements of the system, synergy and STEAM education.

Problem setting. Life in the conditions of market democracy of the latest information technologies is becoming an irreproducible prospect. All this poses a kind of challenge to education, determines the need for its radical modernization. In Ukraine, a strategy of accelerated, anticipatory development of education and science, physical, moral, intellectual and other forces of the individual, which ensure its self-affirmation and self-realization, must be asserted. The «State Standard of Basic and Complete Secondary Education» states that:

the content of the general natural component ensures the formation in the minds of students of the basis for a holistic understanding of nature;

the content of the educational field can be implemented both by separate subjects (astronomy, biology, geography, physics, chemistry and other branches of natural science), which reflect the foundations of the relevant fundamental sciences, and through integrated courses (Державний стандарт базової і повної середньої освіти, 2004).

Problem-based learning has a high developmental effect. The effectiveness of problem-based learning is not in doubt among any of the scientists and teachers, but it is not very often used in school practice. One of the reasons for this is the complex technology of its implementation. Problem-based learning requires a much greater initial time investment, not all topics of the school course of natural sciences are expedient to study by the problem method. Its use is not effective when studying factual material, biographies of scientists, simple formulas.

Analysis of basic research and publications. We see the implementation of the problem-based learning model in a systemic approach (Малафіїк, 2014; Остапчук, 2020; Остапчук, 2005; Остапчук, 2005). The need for a systemic approach in cognition was due to the fact that traditional research methods in the study of complex objects turned out to be ineffective. Therefore, there was a need to present a complex object as a system, as a holistic formation, which allows us to study not only the object itself, but also its connections and relationships. The essence of the systemic approach lies in attempts to further simplify the methods and connections between objects of different nature.

The main concept of the systems approach is the concept of «system». The concept of «system» implies the presence of a set of elements with relations and connections between them, which form a certain integrity. The analyzed concept is characterized by the following provisions relating to the general theory of systems: a system is an integral set of interconnected and interdependent elements; a characteristic property of the system is its hierarchical structure, associated with potential divisibility into sets, associations, etc.; a fully defined place of the system of certain elements in relation to other similar system groups within the general array of elements of a certain type, etc.

The systems approach to the study of objects has a number of advantages: a holistic study of the phenomena of the system leads to a general property that individual elements do not possess; the laws, concepts, ideas that underlie the interconnections of the elements of the system explain its orderliness, organization, development and «behavior» of the system (Малафійк, 2014; Остапчук, 2005).

The purpose of the article. To consider the problem teaching of natural sciences from the point of view of the didactic system, to define and characterize its elements, to show the connections between the elements of the system on the model.

Presentation of the basic material. The didactic system can be considered a general way of implementing the laws and principles of learning. The didactic system belongs to pedagogical systems. Since the pedagogical system is an organized object that manages the process of transferring and assimilating the social experience that humanity has accumulated to date, the didactic system is an organized object with the help of which the teacher ensures the management of the process of transferring and assimilating by students a system of knowledge about society, nature, and man, and on this basis the development of cognitive powers in each of them, the formation of a scientific worldview, a culture of behavior, and positive human qualities (Малафійк, 2014).

The most characteristic feature of this system is its function, in particular, the function of managing the pedagogical process. The participants in this process are the teacher and students. As can be seen from the definition of the didactic system, students and the teacher are not included in its composition as elements. However, it is known that each system lives in a certain environment, surrounded by other systems with which it is connected by certain ties. In some systems, they are so strong that their destruction destroys the system itself. If the teacher and students are not included in the system as its elements, then they, as follows from the definition of the didactic system, are necessarily included in its environment, that is, for the didactic system, the presence of a teacher and students as components of the environment of the didactic system is mandatory. The term «student» means his educational characteristics, abilities, aptitudes, interests, educational experience, peculiarities of thinking, memory, imagination, that is, the student interacts with all elements of the didactic system. The characteristics of the component of the environment of the didactic system «teacher» are his pedagogical experience, knowledge of the educational material, knowledge of the laws of learning, upbringing and development, knowledge of all educational and psychological characteristics of the student, that is, all that allows interaction with each element of

the didactic system and with the entire system. Having strong connections with all elements, or even with the entire didactic system, the environment significantly affects the system as a whole. In general, the didactic system is the didactic space through which the teacher and students interact with each other.

The teacher's actions in problem-based learning are as follows:

1. To set educational tasks for students in an understandable and interesting form.
2. To perform the functions of a coordinator of students' search activities and a partner, to help individual students and groups, differentiating the content of assistance.
3. To be able to confront students with a problem, to stimulate creative thinking with the help of questions.
4. Correctly correct the mistakes made by students in the process of searching for hypotheses and their confirmation.
5. Direct students' activities towards independent mastery of various sources of information.
6. Offer your help only in cases where students cannot make the necessary decision on their own.

Students' actions are guided by the following sequence:

1. Encountering a problem, the emergence of a problem situation.
2. Collecting and analyzing data. Analyzing life experience on the problem, searching for data about objects and phenomena that are not enough to solve the problem.

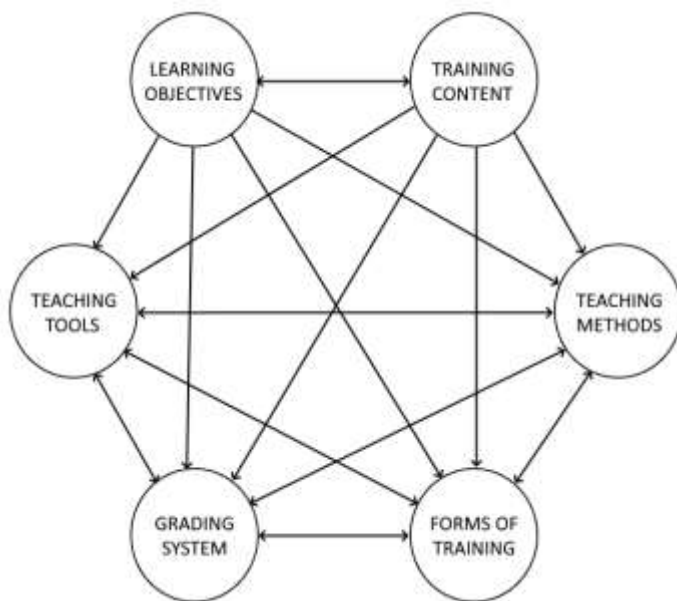


Fig. 1. Model of the didactic system of problem-based learning in natural sciences

3. Determining cause-and-effect relationships, forming a hypothesis. In the event that students are unable to independently put forward a hypothesis, it can be proposed by the teacher.

4. Collecting information, conducting research, studying tables, graphs, reading recommended literature, the result of which is testing assumptions and constructing explanations by students of the situation that led to the problem.

5. Formulating conclusions, analyzing the research process, finding out the cause of the problem situation.

Solving the problems of education, we touch on the content and goals of education, methods, means, organizational forms of education, the system of assessing students' educational achievements. They are interconnected, one determines the other, interact with each other, therefore, they form a holistic whole, which consists of the above-mentioned elements. This whole is the didactic system. So, the didactic system is a set of interconnected elements, which are the goals of education, the content of education, methods, means and organizational forms of education, the system of assessing students' educational achievements. The element «Goals of education» (1) reveals the essence of the problem «Why teach?». «Content of education» (2), answers the question «What to study?», it is determined by the content of education. The third – «Methods of education» (3), reveals the essence of how to achieve the set goals of education, that is, answers the question «How to teach?». «Teaching aids» (4) is the fourth element of the system, it reveals the features of the pedagogical tools and gives an answer to the questions «With what», «With what to teach?». The fifth element of the system – «Forms of organization of teaching» (5), answers the question «In what form, where, when to teach?». The sixth element – «System of assessment of students' educational achievements» (6) shows the achieved competences of students in learning, while simultaneously performing diagnostic, educational, educational, developmental and other functions of educational activity.

The connections between the elements of the didactic system acquire new qualities when this system is included as a component in the system of interaction between the teacher and the student. Then we are dealing with a dynamic system of a higher order, which in its essence is a system of learning, or a pedagogical system.

Let us consider the first element of the didactic system of problem-based learning: «Learning goals». The goal is the final result, the achievement of which is aimed at the efforts of the subject of activity. Learning goals are the result of the joint activity of the teacher and the student, expressed in precise, unambiguous categories and concepts. At this stage of learning, learning is the acquisition of key competencies provided for by the curriculum. The goal of problem-based learning is the assimilation of the results of scientific knowledge, the process of obtaining results, it includes the formation of the student's cognitive independence, and the development of his creative abilities. Attention is paid to the development of thinking, taking into account its patterns. In the conditions of personal learning, we believe that development comes from the inside and is based on natural abilities. The

goals of the developmental group include the development of that mental formation that is characteristic of a given age period, as well as the formation of the skills to compare, analyze, synthesize, abstract, establish cause-and-effect relationships, and transfer actions from one field of knowledge to another. The second element of the didactic system of problem-based learning, «Content of learning», is determined by the content of education at this historical stage. Today, the content of education is oriented towards the State Standard of Basic and Complete General Secondary Education, where, in particular, the content of the natural component creates the prerequisites for ensuring students' awareness of scientific facts, familiarization with the history of the development of natural science, the formation of students' knowledge of basic natural concepts, laws, and processes, for the development of experimental skills and research skills, the ability to apply the acquired knowledge to solve problems and explain phenomena and processes, the formation of students' scientific outlook and thinking style, an idea of the natural picture of the world, and for revealing the role of knowledge of nature in human life and social development (Про деякі питання державних стандартів повної загальної середньої освіти, 2020).

The content of education in personal development education should take into account the individual capabilities of a schoolchild of a given age, promote the development of the student. In addition, the following factors are taken into account: the volume of content, its complexity, difficulty, the nature of cognitive activity, the time of study, etc.

Two trends can change the content of education today. The first of them is associated with the emergence of new data in the field of development of the child's brain and its higher functions. The second is with the formation of a system of continuous education.

The third element «Teaching Methods» shows how the goals set by problem-based learning can be achieved while simultaneously mastering the content of the educational material of the program. Problem-based learning is based on the method of problem-based study of the material. Therefore, in order to reveal the essence of problem-based learning, it is necessary, first of all, to reveal the features of the method of problem-based study of the material, that is, to consider the system of the lower level of the hierarchy, «the process of learning based on solving a problem». The elements of the system are: a) creating a problem situation, b) formulating a problem, c) developing working hypotheses, d) testing working hypotheses; e) analysis of testing working hypotheses, h) return to the problem situation from the point of view of the conclusions obtained.

Let's consider «Teaching aids» – the fourth element of the system. Teaching aids are various materials and tools of the educational process, thanks to which the specified learning goals are achieved more successfully and in a shorter time and the content of the natural science program is mastered. Teaching aids include: textbooks, teaching aids, didactic materials, technical means (TSN), equipment, machines, classrooms, laboratories, computers and other means of mass communication. Real objects, production, structures can serve as teaching aids.

Let's dwell in more detail on didactic materials in problem-based learning in physics. A number of researchers believe that the question «why?» is necessary and main for the formation of the problem, therefore various tasks are created that begin with the question «why?» (Малафійк, 2014; Щербина, 2003). This allows students to logically connect several physical phenomena or concepts, build a chain of connections between these phenomena and concepts, delve into the topic of the phenomenon, which contributes to the development of thinking, creativity, and a deeper understanding of the essence of the subject. But the entire school physics course should not be presented in questions of «why?». This will show their artificiality and complicate the study of the subject. For example, why does the basic formula for calculating the work of current in an electric circuit have the form: $A=IUt$? Because it follows from the concept of voltage – $U=A/q$. Hence $A=Uq$. Since $I=q/t$ and $q=It$, then $A=IUt$. Or, why does the Joule-Lenz law have only one expression out of three, by which one can calculate the amount of heat released in a conductor during the passage of current? Because it is this expression $Q = I^2 R t$ that was obtained experimentally and independently of each other by two physicists Joule and Lenz (Остапчук, 2005).

Solving physical problems in the educational process is the most effective form of deepening, consolidating theoretical material and developing the thinking of schoolchildren. The problematic nature of learning when solving physical problems suggests the systematic use of creative tasks, problem-problems in the educational process (Гончаренко, 1997). A task is problematic or creative if it formulates a certain requirement that is fulfilled on the basis of knowledge of physical laws, but it does not contain direct indications of those physical phenomena, laws that must be used when solving the task [1]. Problem tasks, of course, are used at the final stage of studying the topic, when students have mastered a certain amount of knowledge and after that comes the moment when it is necessary for the knowledge to become active, valid. Problem tasks can also be used: at the beginning of the lesson, in order to increase interest in the material of the topic; in the lesson itself, as a kind of form of studying new material; during questioning, consolidating educational material; in control credit classes; as homework; during independent work of students, thematic certification.

The fifth element of the didactic system is «Forms of organization of learning». The form is an external manifestation of the coordinated activity of the teacher and students, which is carried out in a certain order and mode. Forms of organization of education are classified according to various criteria: by the number of students – individual, group; by the place of study – school, extracurricular, home independent work, classes at the enterprise; by the time of study – in-class, out-of-class, optional, subject circles, quizzes, competitions, Olympiads; by the didactic purpose – lecture, seminar, lesson, paired lessons, paired shortened lessons, «lessons without bells».

The study of physics begins in a comprehensive school from the seventh grade. During this period, the group form of work with students is effective, therefore, in problem-based learning, it is necessary to start with the group form of work (Малафійк, 2014).

The sixth element of the didactic system is the «System of assessing students' educational achievements». In addition to the existing twelve-point system for assessing students' academic achievements in Ukrainian schools, we propose, in particular, for problem-based learning, to take into account the assessment of the child's development. Developmental assessment is a form of procedural assessment, a kind of attempt to document all information about the student's real progress. It assesses the real progress of improving abilities, and not the level of achievements compared to other students. Developmental assessment mostly uses a detailed list of certain expected or desired behavioral changes, which are considered criteria for progress. The most common are so-called checklists, which record specific achievements or abilities in different areas with a certain sequence.

I. Malafiiuk calls problem-based learning a special didactic system. The system is built on a certain understanding of the logical-psychological patterns of the development of thinking and creative abilities of a person. Learning is based on learning by solving problems and has a developmental function in relation to the creative abilities of a person. This type of learning is a system for developing students' creative abilities, and not just a sum or an implicit set of individual methods for activating students' cognitive activity and thinking (Малафіїк, 2014).

The connections between the elements of the didactic system acquire new qualities when this system is included as a component in the system of interaction between the teacher and the student. Then we are dealing with a dynamic system of a higher order, which is essentially a learning system, or a pedagogical system.

Recently, the STEAM education trend has been gaining momentum in the educational space of Ukraine. It covers natural sciences (Science), technologies (Technology), technical creativity (Engineering), art (Art) and mathematics (Mathematics) (Про затвердження плану заходів щодо реалізації Концепції розвитку природничо-математичної освіти (STEM-освіти), 2021).

Probably, by moving from a holistic separate general natural science discipline to the integrity of the cycle of such disciplines and, finally, to the integrity of fundamental natural science and humanitarian education, it is possible to achieve the harmonization of the personality and to implement in education a synthesis of the wisdom of ancient civilizations, modern philosophy, natural science and humanitarian knowledge. In recent decades, such a process began spontaneously as a result of the logic of the development of natural science itself, the integration of its parts, the consideration of increasingly complex systems in physics, chemistry, and biology. In addition, the role of man as an observer and interpreter of the process is now realized (Гончаренко, 2004).

The transition to a new paradigm of education cannot be reduced to a simple increase in the volume of each of the natural science disciplines. An analysis of curricula and programs shows that the possibilities here have already been exhausted. New principles of selection and systematization of knowledge from each discipline and their mutual coordination are necessary.

In this regard, the idea of synergetics has become widespread. The term «synergetics» itself comes from the Greek «synergen» – «assistance», «cooperation», «synthesis of energies». Proposed by G. Haken, this term focuses on

the coherence of the interaction of parts in the formation of a structure as a whole, on the so-called additive effect: «the whole is more than the parts» (Білецький, 2022). Unlike most new sciences, which arose, as a rule, at the junction of two previously existing ones and which are characterized by the mutual penetration of methods and paradigmatic ideologies of different sciences, synergetics arises, relying not on the boundary, but on the internal points of different sciences, with which it shares certain theoretical beliefs: in the systems, regimes and states studied by synergetics, a physicist, a biologist and a mathematician see their material, and each of them, applying the methods of their science, enriches the general stock of ideas and methods of synergetics.

In our opinion, educational subjects should be coordinated not only externally (content of the material studied according to the program, consistency, systematicity, accessibility), but also internally, that is, have the same level of perfection of knowledge of different educational subjects. Let us trace this on the example of studying natural sciences.

The levels of perfection of knowledge are determined by the levels of their mathematization. There are three such levels: the level of elementary processing of empirical data; model-algorithmic; deductive-axiomatic level.

With the general direction of the educational process towards knowledge of the surrounding world, it is important to promote the assimilation of knowledge by students in a continuous complex and interconnectedness, when different educational subjects have the same level of perfection, that is, they require the same way of thinking when understanding them. If at the same time a phenomenon is studied in interdependence (a complex of educational subjects), then this complex of phenomena becomes meaningful knowledge, and the view of the world, thanks to this, expands. If, when studying one subject, the teacher proves a statement at the second level of perfection of knowledge (model-algorithmic) and calls for questioning plausible statements, and when studying another subject, statements are presented or laws are formed with a denial of their truth based only on the statements of authorities, then for primary school students, where the level of perfection of the way of thinking corresponds only to the first level of perfection of knowledge, such statements and laws will not be convincing. Such knowledge is not meaningful and is forgotten after a while. At best, only mentions of authorities and blind faith in them remain. Only after reaching one level of knowledge of the surrounding world (the most common knowledge) can one move on to the second, higher level of knowledge, which corresponds to a more perfect way of learning with the corresponding features of thinking.

Therefore, when studying a discipline in a profile, it is necessary that the subjects constitute an interconnected complex of knowledge of the same levels of perfection. That is, a certain profile of studying a discipline corresponds to the same level of knowledge in other subjects of the natural science cycle: mathematics, chemistry, physics, etc. When studying academic disciplines, there is an internal relationship that does not contradict external intersubject relationships.

Conclusions and prospects for further research. Any system has characteristic features that reflect the nature of the system as a form of its organization into a whole

(the so-called attributive features). For example, these are the following components: components or elements, a system-forming factor, the structure of the system, an emergent property, the presence of a relational influence of the system as a whole, its function and levels of hierarchy. The paper considers the didactic system, defines its components and gives a characteristic of the elements of the didactic system of problem-based learning in natural subjects, the model shows that the system-forming factor is two elements: learning goals and learning content. Other attributive features of the didactic system of problem-based learning in natural sciences require detailed and in-depth research. The internal connections between the elements of the system are emphasized in more detail on the principles of synergy and STEAM education.

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ПЕДАГОГІЧНА СИСТЕМА ВИКЛАДАННЯ ПРИРОДНИЧИХ ДИСЦИПЛІН У ЗАКЛАДІ ЗАГАЛЬНОЇ СЕРЕДНЬОЇ ОСВІТИ

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Анотація. Поняття «система» передбачає наявність множини елементів з відношеннями і зв'язками між ними, що утворюють певну цілісність. У статті розглядається процес навчання з погляду цілісного утворення як педагогічна система із врахуванням компонентів проблемності, як тип навчання, який сприяє розвитку творчих здібностей учнів, а не метод навчальної діяльності. Системне утворення приводить до властивості, якою не володіють окремі елементи. Наведено твердження науковців, щодо компонентів системи навчання, які не є однозначними. Основна увага зосереджена на дидактиці проблемного навчання, менш дослідженими залишаються компоненти освітнього середовища: вчитель і учень. Проблемне навчання є дидактичною системою, так як вона пропонує нову структуру взаємодії учителя і учнів. До елементів дидактичної системи проблемного навчання відносять організація змісту і будови процесу навчання, зміст і методи навчання, побудова системи прийомів пізнавальної діяльності, організація змісту, форми і засоби навчання. Але ми дотримуємося погляду, що дидактична система проблемного навчання шкільного курсу природничих предметів побудована на певному розумінні логіко-психологічних закономірностей розвитку мислення і творчих здібностей людини. Навчання засноване на учінні шляхом розв'язання проблем і володіє розвивальною по відношенню до творчих здібностей людини функцією. Цей тип навчання є системою формування творчих здібностей учнів, а не просто сумою чи неявним набором окремих прийомів активізації пізнавальної діяльності учнів, мислення. Зображено авторську модель дидактичної системи, зокрема, дидактична система – це сукупність взаємозв'язаних елементів, якими є цілі навчання, зміст навчання, методи, засоби і організаційні форми навчання, система оцінювання навчальних досягнень учнів. Дано характеристику складових частин-елементів системи.

Системоутворюючим чинником дидактичної системи є два елементи: цілі навчання і зміст навчання. Більш детально акцентовано внутрішні зв'язки між елементами системи на принципах синергетики і STEAM-освіти. Показано розвивальний ефект проблемного навчання, його переваги і недоліки при вивченні природничих дисциплін. Не всі теми шкільного курсу природознавства доцільно вивчати проблемним методом.

Ключові слова: педагогічна система, проблемне навчання, елементи системи, характеристика елементів системи, синергетика і STEAM-освіта.

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