EFFECTIVE METHODOLOGICAL APPROACHES FOR DEVELOPING INTERDISCIPLINARY INTEGRATION IN PRIMARY EDUCATION THROUGH ARTIFICIAL INTELLIGENCE

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Abstract: This article examines effective methodological approaches to developing interdisciplinary integration in primary education through artificial intelligence. The study focuses on the pedagogical potential of artificial intelligence as an innovative educational tool for establishing meaningful connections among different subject areas and creating an integrated learning environment. Particular attention is paid to the development of methodological approaches that enable teachers to design interdisciplinary learning tasks, adapt educational content to pupils’ individual learning needs, provide personalized feedback, and organize interactive and practice-oriented learning activities. The article analyzes the possibilities of integrating artificial intelligence into interdisciplinary instruction to enhance pupils’ cognitive activity, critical and creative thinking, problem-solving skills, digital competence, and ability to apply knowledge in real-life contexts.

Keywords: primary education, interdisciplinary integration, artificial intelligence, AI-supported learning, methodological approaches, digital competence, critical thinking, creative thinking, problem-solving skills.

Introduction. It is well known that the effectiveness of lessons in primary education can be achieved by organizing the process of developing interdisciplinary integration on the basis of a systematic sequence. Some scholars emphasize that this issue is also addressed in traditional schools through the sequential study of academic subjects. On this basis, they argue that the tradition of teaching subjects separately and systematically is also being established in primary education.

The process of teaching interdisciplinary integration in primary grades based on artificial intelligence plays an important role in both classroom and extracurricular activities within educational institutions. In addition, the organization of extracurricular activities in the form of discussions, meetings, excursions, and clubs focused on interdisciplinary integration creates opportunities for developing students’ scientific worldview.

The following can be identified as components of improving interdisciplinary integration among primary school students based on artificial intelligence:

1. taking into account the values on which each student relies in accordance with the content and essence of improving interdisciplinary integration based on artificial intelligence;

2. students' self-assessment determines their personal position and status;

3. as a result of monitoring the achievement of the current objectives set for the process of improving interdisciplinary integration among students, it becomes possible to determine the outcomes of their intellectual activity.

An analysis of the process of improving interdisciplinary integration among primary school students based on artificial intelligence shows that it is possible to identify the structural components of the activities that ensure this process. They include the following:

1. **In the educational process:** a component that expresses the content of improving interdisciplinary integration based on artificial intelligence. This component incorporates a system of theoretical knowledge that enables students to develop a scientific worldview;

2. **In learning activities:** a component that motivates students to engage in scientific processes. It encompasses didactic methods, principles, work plans, and educational models that enable the development of students' scientific activities;

3. **In the lesson process:** a component aimed at monitoring the level of development of interdisciplinary integration. This component makes it possible to monitor students' level of interdisciplinary integration development and to identify their achievements and shortcomings in scientific activities.

Analysis and results. In primary education and, more generally, in the educational process, the unity and interconnection of all components of any educational system can be regarded as an objective закономерность underlying the existence of differentiation and integration. The problem consists in achieving a dynamic balance between the processes of integration and differentiation within the educational system. Its solution requires harmonizing all organizational and content-related components of the educational process with the aim of achieving the highest possible quality of education [18; p. 48].

The integration of social, natural, and technical sciences demonstrates its close relationship with the contemporary level of scientific development, where integration is clearly manifested. Today, integration is primarily studied at the practical level, particularly at the level of interdisciplinary relationships [111; p. 150].

N.K. Chapayev argues that the selected directions of integration determine the composition and structure of the integrative process. The composition of an integrative process refers to a set of interconnected objects that enter into interaction and form a new integral entity [129; p. 283].

The directions of integration reflect the actual needs that arise among learners and in pedagogical practice in the process of cognition and organization of the educational process. These needs, in turn, arise from contradictions identified by the participants of the pedagogical process during the acquisition of educational material.

However, the study of this phenomenon in education and upbringing is still far from complete. Therefore, A.Ya. Danilyuk notes that the concept of integration has been introduced into the pedagogical context, but its insufficiently developed content does not yet allow it to be fully regarded as a scientific-pedagogical concept based on the educational process [96; p. 24].

In the research works of V.S. Bezrukova, one of the important problems of education—the integration and differentiation of knowledge—has been examined. According to the scholar, integration contributes to establishing structural relationships between different systems of knowledge acquired by students, gradually developing comprehensive and holistic ideas about nature and society, and, on this basis, generalizing all knowledge into a unified system [85; p. 25].

The theory of integration is being developed in connection with and as a result of the development of the concepts of wholeness and systematicity. The principle of systematicity is formed as a holistic approach to research objects. It begins with an understanding of the whole and is further specified through the concepts of system and organization.

I.R. Podlasy defines integration as both a process and a result that creates wholeness by identifying significant relationships between relatively independent components and individual academic disciplines. Based on this concept, it can be stated that the main purpose of integration is not to unify knowledge, but rather to harmonize it in terms of content, organize information belonging to different fields into a coherent system, and improve the quality of information. From this perspective, the introduction of integrated subjects into the educational process makes it possible to develop generalized knowledge. As a result, it creates the foundation for an individual to perceive reality holistically and engage in complex thinking [152].

Methodologists N.M. Verzilin and V.M. Korsunskaya note that interdisciplinary relationships can be of two types: horizontal and vertical. The scholars point out that horizontal interdisciplinary relationships are established between subjects taught within the same grade, quarter, or semester, whereas vertical interdisciplinary relationships are implemented through the use of knowledge acquired in previous grades [91; p. 190].

In his research, M.N. Skatkin distinguishes three types of temporal interdisciplinary relationships: first, the relationship between previously acquired knowledge and the knowledge currently being studied; second, the relationship between the knowledge currently being studied and knowledge that will be acquired in the future; and third, the relationship between knowledge acquired simultaneously [269].

V.N. Maksimova and N.B. Gruzdeva have theoretically and methodologically examined the organization of interdisciplinary relationships in the educational process through a systematic approach. The authors demonstrate the pedagogical foundations for linking biology topics with natural sciences, social sciences, and mathematics, which enables students to systematize their knowledge and apply it in real-life situations. In this process, various types of interdisciplinary relationships—horizontal, vertical, and content-based intersections—are identified, and the methodology for incorporating them into the lesson process is described in detail. The authors also describe methods for developing such forms of knowledge as logical connections, generalization, cause-and-effect analysis, and systematic perception, as well as the opportunities provided by interdisciplinary integration for developing students' creative thinking, analytical approaches, and practical skills [50; p. 192].

V.N. Maksimova also emphasizes the systematic organization of interdisciplinary integration in the educational process. According to the author, interdisciplinary relationships contribute to students' ability to generalize and analyze knowledge and develop practical skills. She proposes teaching subjects through horizontal and vertical connections within learning activities and recommends presenting topics in a logically and substantively interconnected manner.

The practical approaches to interdisciplinary integration include enriching educational material through the methods of causality and consequence, analysis and synthesis, induction and deduction. The author pays particular attention to integrating topics into lesson plans and developing students' independent learning activities. She also emphasizes the possibility of improving the quality of

education and applying knowledge in real-life situations by harmonizing the content of academic subjects with other disciplines [54; p. 143].

K.P. Korolev identifies various forms of temporal interdisciplinary relationships, including connections between teachers and instructional materials, connections between teaching methods and practical activities, connections between general instructional aids and educational materials, as well as the integration of methods from other academic disciplines into the teaching process [269].

In foreign research, the problem of organizing education based on integrative knowledge has also received considerable attention. In pedagogical theory, interdisciplinary integration is interpreted as a means of optimizing educational content, eliminating unnecessary repetition, and enhancing students' cognitive activity. In his concept of optimizing the educational process, Yu.K. Babansky considers integration as a factor ensuring the logical integrity of educational material and emphasizes that education organized on the basis of interdisciplinary integration contributes to students' conscious acquisition of knowledge [23]. M.N. Skatkin, in turn, identifies interdisciplinary integration as an important condition for increasing the effectiveness of the didactic system [107; p. 176].

Furthermore, the extensive interpretation of interdisciplinary integration as a methodological foundation of competency-based education is directly associated with the works of researchers such as I.Ya. Lerner, A.V. Khutorskoy, J. Dewey, J. Bruner, and H. Jacobs. I.Ya. Lerner interprets integration as an important mechanism for developing students' experience in applying knowledge and substantiates the development of skills for solving problem situations on the basis of interdisciplinary knowledge [45; p. 186]. A.V. Khutorskoy closely associates integration with learner-centered and activity-based education, considering it an essential condition for the formation of general educational competencies [125; pp. 58–64].

In pedagogical research conducted in foreign countries, interdisciplinary integration is interpreted in close connection with the concepts of **interdisciplinary** and **transdisciplinary education**. In particular, J. Dewey regards interdisciplinary integration as a factor that enables students to acquire knowledge based on their real-life experiences [153; p. 116]. J. Bruner emphasizes that interdisciplinary integration enables students to understand logical relationships between concepts and transfer knowledge to new situations [144; p. 97]. H. Jacobs scientifically substantiates in her research that integrated

curricula contribute to the development of students' critical and creative thinking [171; p. 204].

V. Boix-Mansilla and Y. Lenoir examine how integration has historically developed within the U.S. education system and emphasize the alignment of interdisciplinary education with educational objectives in the context of contemporary global and technological changes. This provides a theoretical explanation of the pedagogical foundations of interdisciplinary integration in the United States and creates a solid foundation for implementing the interdisciplinary approach in the field of education [145; pp. 1–27].

J. Liu, Y. Watabe, and T. Goto, in their article, provide practical examples of how interdisciplinary integration can be strengthened by incorporating **sustainability** into the curriculum at a Japanese university. They analyze the pedagogical role and limitations of sustainability-related topics in developing interdisciplinary competencies, thereby contributing to the improvement of the effectiveness of the integrative approach [176; pp. 695–710].

Furthermore, the study emphasizes the logical direction of interdisciplinary relationships, the structuring of curriculum topics on the basis of their mutual logical connections, and the necessity for students to apply these logical materials in practice. Within the framework of logical relationships, such processes as comparison, induction and deduction, analysis, synthesis, and generalization are included [269].

In her research, Z.S. Sazonova puts forward the integration of education, science, and production as a methodological basis for training modern specialists. On the basis of this approach, an integrative model aimed at developing professional competencies has been developed. Incorporating activities related to industrial practice into the educational process through this model makes it possible to develop engineering thinking and problem-solving skills. The study also clearly classifies the substantive, organizational, and activity-oriented levels of integration [108; pp. 7–16].

International experience demonstrates that even a simple communicative competency environment based on written correspondence can serve as a basis for achieving positive pedagogical outcomes. The fact that information and didactic tools constitute one of the main forms of organizing learners' online educational activities in different countries demonstrates that solving any problem requires integrated knowledge.

In the modern era, the education system is primarily aimed at establishing a strong foundation in the basic sciences, developing students' thinking, enabling

them to understand and conceptualize the world as an integral whole, correctly comprehend the events occurring in their surroundings, and educate young people who are capable of understanding their essence and significance.

The fragmented nature of academic subjects taught in general education schools may lead to the formation of a fragmented worldview among school students. Consequently, this further demonstrates the growing demand in contemporary science for the integration of economic and political disciplines [16; p. 40].

The foundations for developing a serious and responsible attitude toward the environment are laid in the primary grades. Therefore, new psychological and pedagogical research on educational outcomes related to the first stage of school education makes it possible to reconsider the notion that younger schoolchildren have limited cognitive abilities. This creates a basis for mastering and updating all components of economic education in the primary grades [54; p. 113].

R.A. Mavlonova classifies integrated education in the educational process into several types. In particular, subject integration can also be referred to as universal integration or general integration that replaces several basic system-based courses. For example, the author proposes combining the subjects of native language, reading literacy, natural sciences, mathematics, character education, and music into a single integrated lesson.

In particular, Sh.S. Abdurayimov emphasizes in his research that although such concepts as integration, interdisciplinary relationships, interconnection, and continuity are widely used in pedagogy, many teachers tend to interpret them as having almost the same meaning. However, it is necessary to distinguish these concepts from one another from semantic and methodological perspectives. According to the author, new scientific perspectives have been emerging in recent years concerning the interpretation of relationships between interdisciplinary connections and integration.

In the scientific research of B.S. Abdullayeva, the provision of interdisciplinary relationships among academic subjects in the educational process is methodologically and didactically substantiated as an urgent pedagogical problem.

In the research of A.K. Rakhimov, interdisciplinary integration was implemented with consideration of the content of the subject **“Evolutionary Theory.”** Since the objects of study within the subject “Evolutionary Theory” are interrelated, the research envisages methodological integration, that is, the use of specific methods of scientific inquiry.

According to A.A. Khasanov, interdisciplinary relationships constitute a complex pedagogical problem that reflects the unity and interconnection of educational, воспитательный, and developmental objectives in the teaching process, while their implementation in the educational process is characterized by a comprehensive nature.

Conclusion. Thus, the meaning of the term **"integration"** is interpreted differently depending on the field in which it is applied, the scientific direction, and the functional context. From the perspective of a pedagogical approach, integration is regarded as a particular form of scientific integration implemented within the framework of pedagogical theory and practical activity. It is characterized as a form of unification in which educational objectives, fundamental principles, substantive foundations, and organizational forms demonstrate the highest degree of commonality. Such integration is aimed at strengthening the relationships among various components of the educational and upbringing process, bringing them closer together, and, on this basis, forming larger pedagogical units.

This situation necessitates an examination of the essence of the concept of **"complex."** According to scientific interpretations, in a broad sense, a complex refers to the integration of relatively independent processes in a particular manner within a certain whole [100; p. 49]. However, such wholeness is not merely the result of a simple combination or organizational aggregation of separate components; rather, it is established on the basis of internal, objective, and harmonious relationships among them. Thus, like integration, a complex also expresses the idea of wholeness. Nevertheless, the interactions among its elements and structural components do not reach the same depth and intensity as those characteristic of integration. Therefore, a complex can be regarded not as a complete form of integration, but rather as one of its relatively lower levels or stages.

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