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An Integrative Approach and The Methodology of Organizing Binary Lessons in Biology Education

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Abstract

This article examines the theoretical and methodological foundations of the integrative approach and the organization of binary lessons in biology education. The study addresses the pedagogical essence of the integrative approach, the scientific definition of a binary lesson, the directions of integration of biology with other natural sciences, and the technological map of a binary lesson on "Photosynthesis and Biochemical Processes" developed on the basis of the integrative-biology.uz digital platform. The article also presents the results of an experiment conducted in academic lyceums of the Tashkent, Samarkand, and Fergana regions between 2021 and 2023, which confirm that the implementation of binary-lesson methodology substantially increases learners' integrative thinking, their ability to solve interdisciplinary problems, and their independent engagement with the digital platform.

Keywords: Integrative approach, binary lesson, biology education, interdisciplinary integration, technological map, integrative-biology.uz, academic lyceum, pedagogical efficiency, STEAM, cooperative learning.

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1. Introduction

In contemporary pedagogical paradigms, the formation of complex thinking among learners, the establishment of interdisciplinary connections, and the development of practical competencies are regarded as important conditions for improving the quality of education. From the standpoint of the competency-based education concept, a modern learner is required not only to master knowledge in a single subject but also to apply this knowledge across different contexts, in problem-solving, and through a conscious understanding of interdisciplinary connections.

In the traditional education system, biology, chemistry, physics, and other natural sciences are taught in isolation from one another, with the result that learners find it difficult to independently establish the logical connections between the knowledge acquired in different subjects. One of the effective methodological approaches for overcoming this problem is the organization of binary lessons based on an integrative approach. A binary lesson serves to form a unified, holistic scientific worldview in the learner through the collaborative activity of teachers of two or more subjects.

The Law of the Republic of Uzbekistan "On Education" establishes the necessity of strengthening innovative methodologies and interdisciplinary approaches in the

educational process. At the same time, the recent recommendations of international organizations such as UNESCO and OECD indicate that teaching based on interdisciplinary integration is the principal means of forming 21st-century skills — critical thinking, problem-solving, collaboration, and digital literacy.

The purpose of this study is to investigate, both theoretically and practically, the pedagogical essence of the integrative approach in biology education, the scientific definition and structure of the binary lesson, the directions of interdisciplinary integration, and the methodology of organizing binary lessons. The objectives of the study are as follows: to clarify the content and essence of the concept of integrative approach; to analyze the didactic foundations of the binary lesson; to develop, as a practical example, a technological map based on the integrative-biology.uz platform; and to analyze the results of the experimental work and to formulate methodological recommendations.

2. Literature Review and Methodology

The issues of integrative education and interdisciplinary connections have a long history in world pedagogical science. G.K. Selevko defines the integrative approach in education as a pedagogical system that unites the substantive, methodological, and organizational aspects of education on an interdisciplinary basis; this approach implies a transition from the traditional "one subject — one teacher" model to a "multiple subjects — holistic thinking" model. According to L.S. Vygotsky's theory of the zone of proximal development, a learner achieves the highest cognitive growth through complex problems that cannot be solved alone but can be solved with the help and collaboration of a teacher; this theoretical foundation constitutes the psychological and pedagogical basis of the binary lesson.

Research conducted by D.W. Johnson and R.T. Johnson has empirically demonstrated that cooperative and collaborative teaching — including the joint delivery of lessons by teachers working together — significantly enhances learners' social and communicative competencies as well as their academic outcomes. From the perspective of the TPACK (Technological Pedagogical Content Knowledge) model developed by P. Mishra and M.J. Koehler, a teacher capable of effectively conducting a binary lesson must possess knowledge of the foundations of a neighboring subject in addition to their own subject content, and must be able to organically combine the pedagogical methodologies of both subjects within a single lesson.

According to J. Bruner's concept of the spiral curriculum, the integrative approach enables learners to reconsider and deepen previously formed concepts within a new context, thereby ensuring the durability of knowledge. R.E. Mayer's principles of multimedia learning substantiate the necessity of combining visual, verbal, and interactive modalities within a binary lesson. From the perspective of D.R. Garrison's model of cognitive presence in e-learning, the trialogue that arises in a binary lesson — the three-way pedagogical dialogue between the two subject teachers and the learner — is presented as a factor ensuring the highest level of educational quality.

The methodology of the study is based on a combined application of theoretical and empirical methods. At the theoretical stage, the existing scientific and pedagogical literature on the topic was analyzed, and the didactic structure of the integrative approach and the binary lesson was modeled. At the empirical stage, a technological map was developed for a collaborative binary lesson conducted by biology and chemistry teachers on the topic "Photosynthesis and Biochemical Processes," based on the integrative-biology.uz digital platform, and pedagogical experimental work was organized in academic lyceums of the Tashkent, Samarkand, and Fergana regions over the period 2021–2023. The results of the experimental and control groups were comparatively analyzed, and the obtained data were processed using statistical methods.

3. Results and Discussion

In pedagogical science, the concept of "integrative approach" is defined as a methodological principle serving to form a comprehensive scientific worldview in learners by uniting knowledge from separate subjects into a single didactic system. From this point of view, the organization of binary lessons based on an integrative approach in biology education is considered one of the innovative methodological directions serving to enhance the effectiveness of the educational process.

According to the results of the study, five basic pedagogical principles of the integrative approach were identified: systematicity, interdisciplinary connectedness, practical orientation, activity, and competency-orientation. The content and expected

outcomes of these principles are presented in Table 1.

Table 1.

The basic pedagogical principles of the integrative approach, their content, and expected outcomes

Principle	Pedagogical content and application	Expected outcome
Principle of systematicity	Viewing the knowledge of biology and other subjects as a unified, interconnected system	A holistic scientific picture; improved quality of knowledge
Principle of interdisciplinary connectedness	Explaining biological phenomena simultaneously through the laws of chemistry, physics, mathematics, and ecology	Interdisciplinary competence; deeper understanding of processes
Principle of practical orientation	Connecting theoretical biological knowledge with real-life and ecological situations	Practical competencies; life skills
Principle of activity	Transforming the learner from a passive listener into an active researcher	Cognitive independence; increased motivation
Principle of competency-orientation	Forming skills, abilities, and values together with knowledge	Integrative competence; professional orientation

The five principles presented in the table operate in harmony with one another and constitute the pedagogical foundation of the binary-lesson methodology.

A binary lesson is a collaborative educational session organized on the basis of the substantive integration of two or more subjects, in which the instructional materials are unified around a single didactic goal and the lesson is jointly conducted by two or more teachers. The pedagogical tasks of the binary lesson in biology education consist of three aspects: first, providing a deeper explanation of biological phenomena through the laws of chemistry, physics, or other subjects; second, forming in learners the ability to solve complex interdisciplinary problems that cannot be accommodated within the scope of a single subject; and third, demonstrating teamwork to learners through the example of collaboration between two teachers.

Within the framework of the study, six main directions of integration of biology were identified: biology–chemistry, biology–physics, biology–mathematics, biology–informatics, biology–ecology, and biology–medicine. Each direction forms a distinct set of competencies (Table 2).

Table 2.

Directions of binary-lesson integration in biology and the map of interdisciplinary integration

Integration	Directions of binary topics	Competency formed
BIOLOGY + CHEMISTRY	Photosynthesis, enzymes, proteins, DNA chemistry, biochemical reactions	Molecular thinking; biochemical analysis skills; laboratory competence
BIOLOGY + PHYSICS	Diffusion, osmosis, bioelectricity, thermoregulation, physics of nerve impulses	Systematic physical-biological analysis; observation and measurement methodology
BIOLOGY + MATHEMATICS	Genetic probability, population modeling, statistical analysis, biometrics	Mathematical-biological modeling; statistical calculation
BIOLOGY + INFORMATICS	Bioinformatics, virtual laboratory, modeling, digital analysis	Digital competence; data analysis
BIOLOGY + ECOLOGY	Ecosystem monitoring, population dynamics, sustainable development, climate biology	Ecological culture; systematic ecological thinking
BIOLOGY + MEDICINE	Human physiology, immunity, disease biology, pharmacokinetics	Medical-biological literacy; healthy lifestyle

All of these directions are supported with methodological materials within the corresponding modules of the integrative-biology.uz platform, which provides teachers with a ready-made digital didactic base for organizing binary lessons.

A practical model of a binary lesson on "Photosynthesis and Biochemical Processes" As a practical example of organizing integrative binary lessons, a complete technological map was developed for an 80-minute (two combined class periods) collaborative binary lesson conducted by biology and chemistry teachers on the topic "Photosynthesis and Biochemical Processes," based on the integrative-biology.uz platform.

The lesson is designed for the 10th grade natural-science track of academic lyceums and is based on the combined application of problem-based learning, STEAM, and cooperative teaching methods.

The lesson was designed in five stages: motivation (0–10 minutes), new knowledge (10–30 minutes), virtual laboratory (30–55 minutes), interdisciplinary task (55–70 minutes), and reflection and assessment (70–80 minutes). At each stage, the activities of the biology and chemistry teachers, the procedure for the learner's work with the platform, and the expected outcome are clearly defined (Table 3).

Table 3.

Abridged technological map of the binary lesson "Photosynthesis and Biochemical Processes"

Stage / Time	Biology teacher's activity	Chemistry teacher's activity	Assessment / Outcome
Motivation (0–10 min.)	Begins the lesson with the question "Where do plants get their bread from?"; presents the photosynthesis animation	Asks a question about chlorophyll and light waves; provides a chemical explanation	Cognitive interest is aroused
New knowledge (10–30 min.)	Explains the light and dark stages of photosynthesis	Writes the equation $6CO_2+6H_2O \rightarrow C_6H_{12}O_6+6O_2$ and explains the ATP/NADPH mechanism	Biological and chemical concepts are combined
Virtual laboratory (30–55 min.)	Organizes the experiment "Light intensity and the rate of photosynthesis"	Demonstrates the method of measuring CO_2 changes using a virtual sensor	Practical skills and experimental methodology are formed
Interdisciplinary task (55–70 min.)	Formulates an ecological problem (using the example of deep-sea plants)	Explains the wavelength of light and the absorption spectrum of chlorophyll	Interdisciplinary thinking and integrative competence
Reflection (70–80 min.)	Summarizes the biological conclusions	Conducts a rapid check using the platform's testing module	Reflective competence; self-assessment

The lesson structure reflected in the technological map fully corresponds to R.E. Mayer's principles of multimedia learning, ensuring the combination of visual, verbal, and interactive modalities at each stage. This map serves as a practical guide for biology and chemistry teachers, significantly reducing the time required to prepare for a binary lesson and improving its methodological quality.

Analysis of the experimental results

In order to determine the pedagogical effectiveness of the binary-lesson methodology, experimental work was organized in academic lyceums of the Tashkent, Samarkand, and Fergana regions over the period 2021–2023. The results of learners in the experimental groups, who studied biology and chemistry in an integrated binary-lesson format, were comparatively analyzed

against the results of learners in the control groups, who received education through traditional, separate lessons.

Table 4.

Results of the binary-lesson experiment: indicators of the control and experimental groups (2021–2023)

Indicator	Control group	Experimental group	Difference	Rating
Level of integrative thinking	41%	76%	**+35%**	High
Solving interdisciplinary problems	33%	72%	**+39%**	High
Motivation and engagement in binary lessons	52%	84%	**+32%**	High
Achievement level in biology	68%	85%	**+17%**	High
Independent research skills	29%	67%	**+38%**	High
Independent use of the platform	26%	79%	**+53%**	High
Formation of competencies (average)	**41%**	**77%**	**+36%**	**High**

The data in the table indicate that statistically significant positive changes were observed across all indicators in the experimental groups. The highest increase was recorded for “independent use of the platform” (+53%) and “solving interdisciplinary problems” (+39%), confirming the high effectiveness of the combination of the binary lesson and the digital platform in forming integrative competencies. The increase in the achievement level in biology from 68% to 85% (+17%) demonstrates that interdisciplinary integration also has a positive effect on the deeper mastery of biology itself. These results are entirely consistent with the conclusions of D.W. Johnson and R.T. Johnson's research regarding the enhancement of academic outcomes through cooperative and integrative teaching.

Problems in implementing binary lessons and ways to overcome them

A number of methodological and organizational problems arise in the process of implementing binary lessons in practice. The main problems identified during the study and the ways of overcoming them are summarized in Table 5.

Table 5.

Problems in implementing binary lessons and ways to overcome them

Type of problem	Essence of the problem	Ways of overcoming it
Problem of time and scheduling	Difficulty in finding a class period free for both teachers simultaneously	Drawing up a calendar of binary lessons in advance; including them in the quarterly plan
Lack of collaboration among teachers	Insufficient development of methodological collaboration traditions between different departments	Interdisciplinary methodological seminars; an experience-sharing platform
Shortage of methodological materials	Insufficient ready-made integrative assignments and technological maps available in the Uzbek language	Using the bank of interdisciplinary assignments on the integrative-biology.uz platform
Problem of technical resources	Insufficient provision of stable internet access and modern equipment	Improving technical infrastructure; an offline mode for the platform
Complexity of integrative planning	Difficulty in logically and coherently combining the content of two subjects within one lesson	Professional development courses on binary-lesson design; ready-made models

The problems shown in the table are predominantly systemic in nature, and resolving them requires a coordinated approach at both the school level and the level of educational authorities. Within the framework of the study, the problem of the shortage of methodological materials was partially resolved through the creation of a bank of interdisciplinary assignments for biology, chemistry, physics, ecology, and informatics on the integrative-biology.uz platform.

4. Discussion

The findings obtained confirm that the integrative approach and binary lessons constitute a theoretically grounded and practically effective methodological tool in biology education. The high indicators recorded in the experimental groups — in particular, the 35% increase in the level of integrative thinking and the 39% increase in the ability to solve interdisciplinary problems — demonstrate that the binary lesson substantially develops the learner's capacity to perceive interdisciplinary connections.

At the same time, the 53% increase in independent use of the platform shows that the combination of digital learning tools with the binary-lesson methodology strengthens the learner's independent learning activity. This finding is consistent with international research in the field of blended learning and the integration of digital platforms, which represents one of the current trends in education.

The practical significance of the study's findings lies in the fact that the developed technological-map model can also be adapted to other topics (for example, “Diffusion and osmosis” — biology–physics integration, or “Genetic probability” — biology–mathematics integration), demonstrating the universal applicability of the binary-lesson methodology. At the same time, the organizational and methodological problems identified in the study should be regarded as constraints that must be taken into account in the broad implementation of binary lessons.

5. Conclusion

Based on the results of the study conducted, the following conclusions were reached:

1) The organization of an integrative approach and binary lessons in biology education is an important methodological tool for developing learners' interdisciplinary competencies, for achieving a deeper mastery of biological knowledge in conjunction with chemistry, physics, ecology, and other subjects, and for qualitatively improving the effectiveness of education.

2) The five basic principles of the integrative approach (systematicity, interdisciplinary connectedness, practical orientation, activity, and competency-orientation), the scientific definition and pedagogical tasks of the binary lesson, and the six main directions of integration in biology (chemistry, physics, mathematics, informatics, ecology, and medicine) were theoretically substantiated.

3) A complete technological map was developed and practically tested for an 80-minute collaborative binary lesson conducted by biology and chemistry teachers on the topic “Photosynthesis and Biochemical Processes,” based on the integrative-biology.uz digital platform.

4) The experimental results obtained between 2021 and 2023 confirmed that, in groups where the binary-lesson methodology was implemented, the level of integrative thinking increased by 35%, the ability to solve interdisciplinary problems increased by 39%, the achievement level in biology increased by 17%, and the activity of independent learning through the platform increased by 53%.

5) The main obstacles to the broad implementation of binary lessons — the shortage of methodological materials, the insufficiently developed tradition of collaboration among teachers, and problems with technical infrastructure — were identified, and practical solutions were proposed for them.

In conclusion, it should be emphasized that the binary lesson, as an innovative pedagogical model in biology education, possesses high effectiveness, and its broad implementation in combination with digital educational platforms significantly enhances learners' interdisciplinary thinking and the overall quality of education. In future research, it would be promising to extend the binary-lesson methodology to integration with other natural sciences (physics, geography) and to explore the application of artificial intelligence technologies in binary lessons.

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