https://ijmsphr.com

DOI: - 10.37547/ijmsphr/Volume07Issue05-06

Open Access

Research Paper

INTERNATIONAL JOURNAL OF MEDICAL SCIENCE AND PUBLIC HEALTH RESEARCH

Vol. 07, No. 05, May 2026, 24-27

eISSN 2767-3774

# Methods for Developing Students' Interdisciplinary Integrative Thinking Competencies in Teaching Biology

**G'aniyeva G. I**

**Senior Lecturer, Department of Botany, Termez State University, Doctor of Philosophy in Pedagogical Sciences (PhD), Uzbekistan**

**Jumaev Y. Q.**

**Independent Researcher, Uzbekistan**

Article Received: 28/03/2026, Article Accepted: 25/04/2026, Article Published: 14/05/2026

**Abstract**

**This article highlights the scientific-theoretical and practical-methodological foundations of developing students' interdisciplinary integrative thinking competencies in teaching biology. The study is aimed at developing students' holistic scientific worldview, analytical thinking, creativity, inventiveness, reasoning skills, and ability to solve problem-based situations by teaching biological topics in close connection with physics, chemistry, and mathematics. The article analyzes the effectiveness of the proposed methodology based on an interdisciplinary integrative lesson model, a system of tasks, assessment criteria, and the results of pedagogical experimental work.**

**Keywords:** Biology education, interdisciplinary integration, integrative thinking, competence, creativity, inventiveness, STEM, problem-based learning, physics, chemistry, mathematics.

## Introduction

In the modern education system, students are expected not only to acquire ready-made knowledge, but also to analyze knowledge through interdisciplinary connections, find solutions to practical problems, and generate new ideas as essential competencies. In the PISA 2022 assessment framework, the ability of students to apply knowledge in various contexts, analyze problem-based situations, and think creatively is identified as an important indicator, rather than merely recalling information.

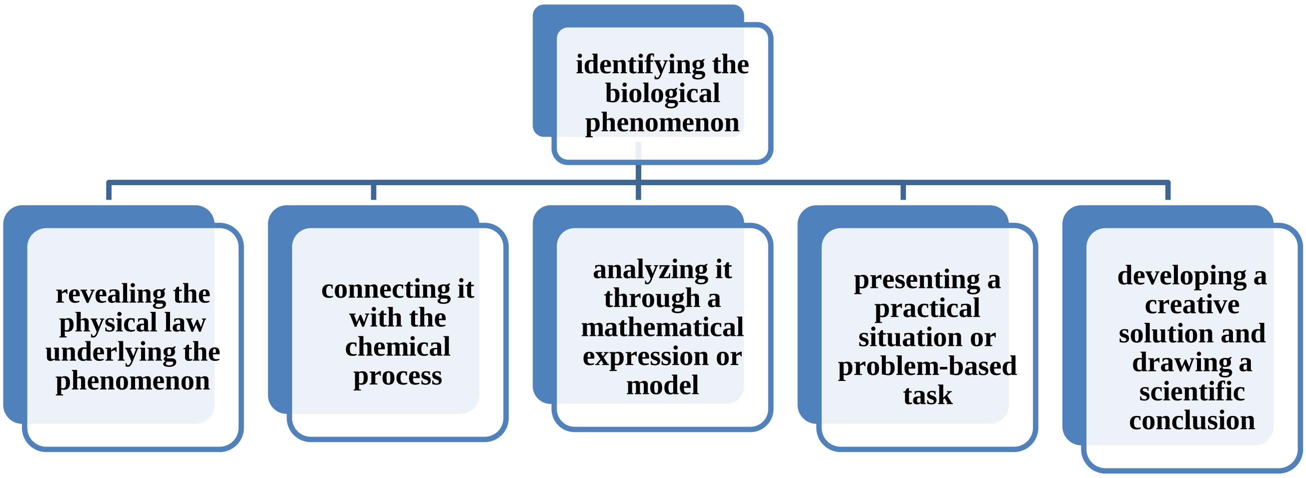
Biology has significant didactic potential in this regard. This is because almost all processes occurring in living organisms are manifested not only as biological phenomena, but also as complex systems closely related to physical laws, chemical reactions, and mathematical relationships. In the K–12 Science Education framework developed by the National Research Council, the integration of "science practices", "crosscutting concepts", and "disciplinary core ideas" is defined as a key didactic direction in teaching natural sciences [2, pp. 1–4]. For example, the process of photosynthesis is associated with the conversion of light energy into chemical energy; the circulatory system is related to pressure and fluid movement; respiration is connected with gas diffusion and oxidation reactions; and population dynamics is linked to mathematical modeling. Therefore, teaching biology in connection with physics, chemistry, and mathematics creates opportunities for students to understand topics deeply, holistically, and systematically. As Bybee emphasizes, STEM education is not merely a collection of separate disciplines, but an educational approach aimed at solving real-life problems through the integration of different fields [3, pp. 5–12]. From this perspective, teaching biology on an integrative basis serves as an important pedagogical mechanism for developing students' scientific thinking, creativity, inventiveness, and problem-solving competencies.

In biology education, the traditional approach is often focused on explaining topics through separate biological concepts. Although this approach forms a certain level of theoretical knowledge in students, it does not sufficiently contribute to a deep understanding of the physical, chemical, and mathematical essence of biological processes. As a result, students may memorize the topic, but they may not be able to independently analyze its mechanism, causes, quantitative expression, and practical significance.

International studies on interdisciplinary science teaching indicate that an interdisciplinary approach helps students analyze natural phenomena not within a single discipline, but through the integration of various scientific concepts [4, pp. 66–74]. This approach is especially important in biology for developing students' scientific literacy and logical analytical skills.

The relevance of the study is determined by the following factors: first, there is a need for a methodological model based on interdisciplinary integration in biology education; second, linking biological topics with physics, chemistry, and mathematics ensures deeper and more conscious learning; third, the integrative approach develops creativity, inventiveness, critical thinking, and problem-solving competencies; fourth, interdisciplinary tasks transform students from passive listeners into active observers, analysts, and researchers. The study employed theoretical analysis, pedagogical observation, comparative analysis, competency-based approach, interdisciplinary integration approach, problem-based learning, project method, development of integrative tasks, and pedagogical experimental methods. The object of the study was the process of teaching biology in general secondary schools. The subject of the study was the content, methods, tools, and pedagogical conditions for developing students' interdisciplinary integrative thinking competencies through teaching biological topics in integration with physics, chemistry, and mathematics.

The methodological model was developed based on the following sequence:




This model corresponds to the principles of integrated STEM education, which are based on interdisciplinary connectivity, orientation toward real-life problems, and the active position of the learner [5, pp. 1–11]. In the integrated STEM concept proposed by Kelley and Knowles, interdisciplinary connection, contextual problem-solving, and students' active constructive participation are identified as key elements [5, pp. 2–5]. When biology is taught through an interdisciplinary integrative approach, students study each biological phenomenon from the perspectives of several disciplines. This process is organized on the basis of the following algorithm: "biological phenomenon — physical law — chemical process — mathematical expression — practical solution. For example, in the topic "The Circulatory System," heart activity is studied from a biological perspective as a process that supplies body tissues with oxygen and nutrients. When connected with physics, blood pressure, fluid flow, and the mechanical work of the heart are analyzed. When linked with chemistry, the binding of hemoglobin with oxygen and the transport of carbon dioxide are explained. From a mathematical perspective, analysis is carried out using pulse rate, blood pressure indicators, average values, percentages, and graphs.

In the topic "Photosynthesis," students study the process not only as the formation of organic matter in plants, but also as the conversion of light energy into chemical energy, the reaction of carbon dioxide and water, and the quantitative expression of glucose formation. Such an approach develops students' ability to understand biological processes comprehensively and to draw scientifically grounded conclusions.

During the study, it was found that biology lessons organized on the basis of an interdisciplinary integrative approach had a positive effect on students' deep understanding of the subject matter, their ability to analyze biological processes in connection with different disciplines, and their capacity to draw practical conclusions.

In the experimental classes, students actively used physical, chemical, and mathematical concepts while studying biological topics. They learned not only to describe biological phenomena, but also to explain their mechanisms, causes, quantitative expressions, and practical significance.

According to the results of the pedagogical experiment, the level of acquisition of interdisciplinary integrative thinking competencies among students in the experimental classes was 10.7% higher than that of students in the control classes. This difference was interpreted using the $\chi^2$ — chi-square method of mathematical statistics. This result indicates the effectiveness of the integrative methodology in developing students' analytical thinking, understanding of interdisciplinary connections, problem-solving skills, and creative approach.

**The experimental results demonstrated the following positive changes:**

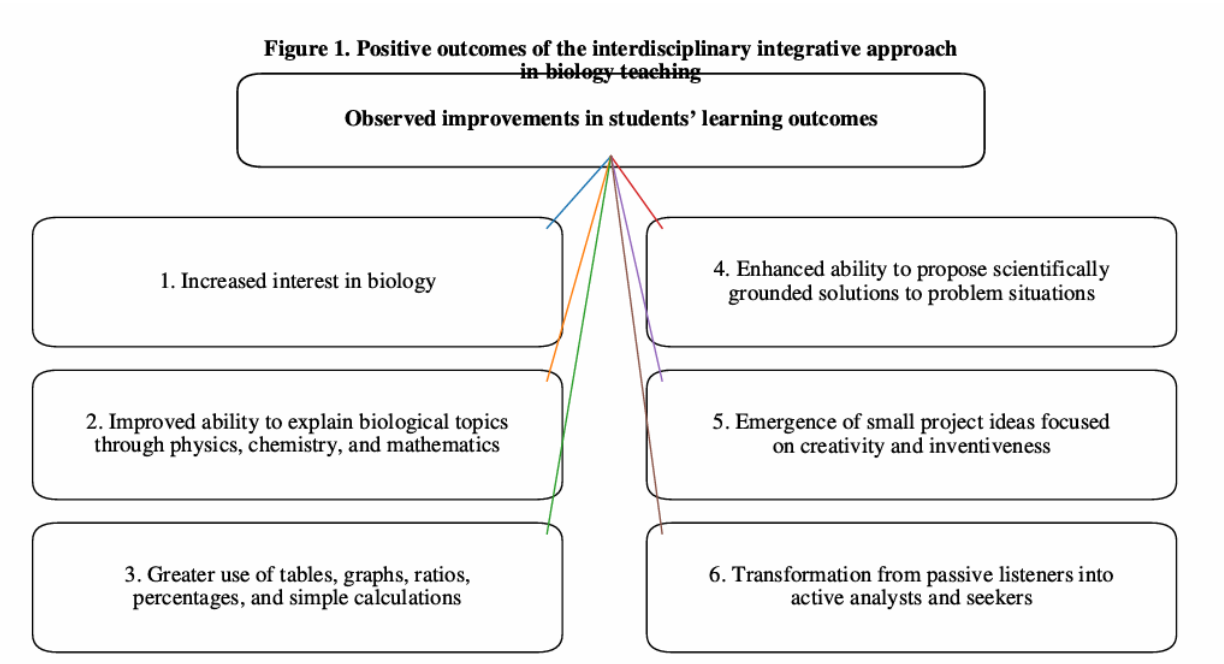



**Figure 1. Positive outcomes of the interdisciplinary integrative approach in biology teaching.**

The diagram presents the key positive changes observed in the experimental classes, including increased interest in biology, improved interdisciplinary explanation skills, enhanced use of analytical tools, stronger problem-solving ability, the emergence of creative project ideas, and the transformation of students into active analytical learners.

## Discussion

The research findings showed that teaching biology on the basis of an interdisciplinary integrative approach contributes to students' deep and conscious acquisition of knowledge. These findings are consistent with international studies indicating that STEM integration develops students' conceptual understanding, critical thinking, and practical problem-solving skills [1, pp. 145–152; 6, pp. 35–60].

Moore et al. note that integrated STEM activities in K–12 education enable students to connect theoretical knowledge with real-life problems [6, pp. 35–60]. The results of the present study also demonstrated that the use of interdisciplinary tasks in biology transforms students' theoretical knowledge into practical, analytical, and creative activity.

The effectiveness of the integrative methodology lies in the fact that it turns students from passive recipients of ready-made information into active subjects who ask questions, search for answers, conduct experiments, perform calculations, compare results, and draw conclusions. Within the PISA 2022 framework, the OECD characterizes creative thinking as students' ability to generate diverse and original ideas, evaluate them, and improve them. In this regard, integrative tasks aimed at creativity and inventiveness in biology lessons directly contribute to the development of these competencies.

The research results showed that topics such as "Photosynthesis," "Respiration," "Circulation," "Metabolism," "Water Movement in Plants," and "Population Dynamics" have high didactic potential for interdisciplinary integration. In this process, students do not memorize biological processes one-sidedly; rather, they understand their physical mechanisms, chemical essence, and mathematical expression.

## Conclusion

Teaching biology in integration with physics, chemistry, and mathematics is an effective methodological approach for developing students' interdisciplinary integrative thinking competencies. This approach contributes to the deep, holistic, and scientifically grounded explanation of biological topics, as well as to the development of students' analytical thinking, creativity, inventive potential, and ability to solve problem-based situations.

According to the research results, the level of interdisciplinary thinking competencies among students in the experimental classes, where the integrative methodology was applied, was 10.7% higher than that of students in the control classes. This difference was statistically interpreted using the $\chi^2$ method. This confirms that the systematic implementation of interdisciplinary integration in biology education is an important pedagogical factor in improving students' knowledge quality and developing their scientific-practical thinking.

## References


1. Honey M., Pearson G., Schweingruber H. STEM Integration in K–12 Education: Status, Prospects, and an Agenda for Research. Washington, DC: The National Academies Press, 2014. 180 p. Used pages: 13–16, 145–152. DOI: 10.17226/18612.

2. National Research Council. A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Washington, DC: The National Academies Press, 2012. 400 p. Used pages: 1–4, 41–82. DOI: 10.17226/13165.

3. Bybee R.W. The Case for STEM Education: Challenges and Opportunities. Arlington, VA: NSTA Press, 2013. 116 p. Used pages: 5–12, 103–109.

4. You H.S. Why Teach Science with an Interdisciplinary Approach: History, Trends, and Conceptual Frameworks. Journal of Education and Learning. 2017;6(4):66–77. DOI: 10.5539/jel.v6n4p66.

5. Kelley T.R., Knowles J.G. A Conceptual Framework for Integrated STEM Education. International Journal of STEM Education. 2016;3:Article 11. pp. 1–11. DOI: 10.1186/s40594-016-0046-z.

6. Moore T.J., Stohlmann M.S., Wang H.H., Tank K.M., Glancy A.W., Roehrig G.H. Implementation and Integration of Engineering in K–12 STEM Education. In: Purzer Ş., Strobel J., Cardella M., editors. Engineering in Pre-College Settings: Research into Practice. West Lafayette: Purdue University Press; 2014. pp. 35–60.

7. OECD. PISA 2022 Assessment and Analytical Framework. Paris: OECD Publishing, 2023. Used sections: Mathematics Framework; Creative Thinking Framework.

8. OECD. PISA 2022 Creative Thinking. Paris: OECD, 2024. Creative Thinking Assessment Framework.

9. Yakman G. STEAM Education: An Overview of Creating a Model of Integrative Education. PATT Conference Proceedings. 2008. pp. 1–28.

10. Tripp B., Shortlidge E.E. A Framework to Guide Undergraduate Education in Interdisciplinary Science. CBE—Life Sciences Education. 2019;18(2):1–12.

11. G.I. G'aniyeva INTEGRATIVE TEACHING TECHNOLOGY OF BIOLOGY, PHYSICS AND CHEMISTRY THROUGH INFORMATION TECHNOLOGIES. ISSN 2311-2158. The Way of Science. 2025. № 11 (141), Vol. II

12. G.I. G'aniyeva DEVELOPING STUDENTS' INTERDISCIPLINARY THINKING THROUGH GAMIFICATION ELEMENTS. ISSN 2311-2158. The Way of Science. 2025. № 11 (141), Vol. II.