INNOVATIVE METHODOLOGY FOR ORGANIZING BIOLOGY EDUCATION BASED ON THE 5I MODEL (ON THE EXAMPLE OF THE SUBJECT "SOLVING PROBLEMS AND EXERCISES IN BIOLOGY")

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ANNOTATION: This article analyzes an innovative methodology for organizing biology education based on the 5I model. Using the subject "Solving Problems and Exercises in Biology" as an example, the five stages of the 5I model - Integration, Inversion, Innovation, Immersion, and Interpretation - are linked with pedagogical approaches, with each stage illustrated through practical classroom applications. The model is grounded in its potential to enhance student engagement, develop critical thinking, and foster independent scientific reasoning. The findings also highlight that the 5I model can serve as a solid foundation for the effective implementation of interactive, contextual, and innovative methods in biology education. The results of the research provide a scientific and practical basis for organizing the learning process more effectively.

KEY WORDS: 5I model, biology education, problem and exercise solving, integration, inversion, innovation, immersion, interpretation.

INTRODUCTION

In recent years, there has been a gradual shift in biology education from traditional knowledge transmission models toward more student-centered, active learning approaches. In particular, pedagogical methods such as Active Learning, Problem-Based Learning (PBL), and Inquiry-Based Learning (IBL) have gained prominence as effective strategies for developing biological competencies [1; 2; 3].

Problem-Based Learning (PBL) focuses the learning process on solving real-life problems. In this model, learners do not acquire knowledge in a ready-made form but rather construct it through solving practical tasks. PBL fosters essential skills such as independent thinking, collaboration, critical analysis, decision-making, and the ability to justify one's own viewpoint. In biology education, such problems can range from genetic disorders to various ecological crises [6; 9].

Inquiry-Based Learning (IBL), on the other hand, directly involves students in scientific inquiry. Learners formulate their own questions, develop hypotheses, conduct experiments, analyze results, and draw conclusions [3]. This approach not only enables students to gain knowledge but also teaches them how to generate and apply it independently. It aligns particularly well with the nature of biological sciences, which are rooted in observation, experimentation, and analysis [4].

Interactive methods that promote active engagement-such as Audience Response Systems (ARS) and Guided Inquiry Worksheets (GIW)-allow learners to immediately test their knowledge, respond to variables, and reflect on their understanding. These technologies support not only the consolidation of conceptual knowledge but also the development of metacognitive awareness and quantitative reasoning skills [1; 5].

Through the use of these innovative pedagogical strategies, students in modern biology classrooms are transforming from passive recipients of knowledge into active seekers, problem-solvers, and analytical thinkers. This transformation reflects the core principles of 21st-century education-functional literacy, problem-solving, creativity, and digital competence-and contributes to the formation of an integrative learning model [7].

In the process of mastering biology in a deep and functional manner, the activity of solving problems and exercises plays a crucial role. This methodological approach helps develop students' analytical thinking skills, enhances their understanding of interdisciplinary connections, fosters the analysis of cause-and-effect relationships, and builds the capacity to apply scientific knowledge to real-life situations [5].

From a didactic perspective, solving biological problems is not merely a tool for reinforcing content knowledge, but a strategic method for gradually developing scientific thinking, critical reasoning, and decision-making skills in learners. In particular, when solving problems in genetics, ecology, physiology, and biochemistry, students do not simply repeat knowledge—they apply it in new contexts. This activates the higher-order levels of Bloom's taxonomy: applying, analyzing, evaluating, and creating [2].

International pedagogical literature emphasizes that engaging students in solving biological problems contributes to the formation of expert-level scientific thinking. For example, a study published in CBE–Life Sciences Education by T. K. Crowe and colleagues highlights the importance of integrating conceptual, quantitative, and metacognitive approaches to promote deep understanding of biological concepts. In this approach, students are not merely memorizing facts but learning to analyze them systematically and apply them to novel situations.

Furthermore, Anderson and Finnish researchers point out that problem-based learning maintains a balanced cognitive load while simultaneously activating students' transfer skills-that is, the ability to apply learned knowledge in unfamiliar contexts. This is particularly important in biology, where students must navigate complex terminology, systemic processes, and dynamic variables.

Another critical aspect of solving biological problems is the frequent integration of interdisciplinary knowledge. For instance, in genetics problems, students must often apply concepts from mathematical combinatorics, statistics, and probability theory. This not only strengthens cross-curricular integration, but also teaches students to approach science in a more holistic and systemic manner [10].

MAIN PART. Today, a variety of modern approaches are being applied to enhance the effectiveness of education, among which models such as 4C (Creativity, Critical Thinking, Collaboration, Communication), 5E (Engage, Explore, Explain, Elaborate, Evaluate), and SAT are particularly noteworthy. Based on these frameworks, the 5I model has been introduced into pedagogical practice.

The 5I model, originally developed by Associate Professor U. E. Rakhmatov, represents a unique scientific-methodological approach that integrates interactivity, analytical thinking, and modern competencies into biology education. This model takes into account the specific nature of biology as a subject—its complexity, interdisciplinarity, systematicity, and dynamism-and aims to cultivate learners as active, inquisitive, and creative individuals.

The 5I model is a step-by-step methodological approach designed to organize the biology teaching process in an innovative, consistent, and systematic manner. It consists of the following five stages: Integration, Inversion, Innovation, Immersion, and Interpretation. Each stage is grounded in a specific pedagogical paradigm and didactic strategy, which makes the model relevant to contemporary education.

1. Integration. This stage emphasizes interdisciplinary links to promote deeper understanding of biological problems, the establishment of connections between different areas of knowledge, and problem-solving in biology. It is theoretically based on Constructivist Learning Theory (Piaget, Vygotsky), where knowledge is formed through interrelations [1], and Contextual Learning, which emphasizes learning in real-life contexts [8]. Practically, this involves analyzing biological problems (e.g., in genetics) in connection with chemistry (molecular structure), informatics (bioinformatics tools), or physics (radiation effects). Learners are trained to apply interdisciplinary approaches during independent analysis of biological topics.

2. Inversion. This stage is based on analyzing educational content in reverse order (from outcome to cause). It is underpinned by Problem-Based Learning (PBL)-a strategy that starts with finding solutions and works backward to identify causes [9,6], and Backward Design (Wiggins & McTighe), where objectives are defined first, followed by the development of learning paths. In biology, this is applied through analyzing genetic changes based on disease symptoms, solving problems related to protein biosynthesis, or identifying causes of chromosomal mutations. As a result, this stage supports the development of analytical and critical thinking, as well as reverse logical reasoning skills.

3. Innovation. This stage focuses on solving biological problems using modern technologies, information resources, and methods. It is grounded in Digital Pedagogy, which emphasizes the integration of digital tools in teaching [8].

In biology, this includes the use of VR laboratories, CRISPR simulators, DNA analysis tools, solving problems related to the molecular basis of heredity, and using interactive platforms like Kahoot and Quizizz. The goal is to develop learners' abilities to work with modern technologies and enhance creative and functional literacy [7].

*4. Immersion.*This stage involves "immersing" the learner in a biological environment to ensure deep understanding through real-world contexts. Theoretically, it draws on Situated Learning [10], where knowledge is acquired through real-life experiences, and Sociocultural Theory (Vygotsky), which emphasizes the role of social context in shaping learning.

In biology, this includes ecological observations, field experiments, laboratory work, and direct study of biological materials. The didactic aim is to reinforce knowledge through real-life experience, transforming the learner from a passive receiver into an observer and researcher.

5. Interpretation. This final stage involves interpreting acquired knowledge and data, analyzing, and drawing conclusions. It is based on Reflective Practice (Schön, 1983), which encourages learners to reflect on what they have learned, and Metacognition, which focuses on awareness and regulation of one's own thinking process (Bransford et al., 2000). In biology, this may include writing reports on experiments, giving presentations, participating in group discussions, and answering open-ended questions like "What if...?" to broaden their understanding. The main didactic purpose is to help learners independently analyze their knowledge, generate new ideas and conclusions, and express their personal scientific viewpoints.

Although the 5I model has not yet been widely explored under this specific term in either international or local academic literature, a number of related approaches that align with its core principles have been implemented in other subject areas. These parallels are illustrated in Table 1.

Table 1.

Subject	**Corresponding Approach**	**Reference (if available)**
Physics	Inquiry-based labs, Reverse engineering	Etkina et al. (2020), Inquiry in STEM
Chemistry	Context-based learning, Simulations	Bennett & Lubben (2006), Context-based Chemistry
Computer Science	Computational thinking via problem solving	Wing (2006), Computational Thinking
Medicine	Case-based reasoning, Virtual patient systems	Eva (2005), Diagnostic reasoning in medical education
Geography	Field-based learning, GIS immersion	Bednarz (2004), Geospatial thinking in education

All of these models correspond closely to key phases of the 5I model, particularly Integration, Immersion, and Innovation.

We believe that the 5I model, by its very nature, serves as a pedagogical approach that transforms the learner from a passive recipient of knowledge into an active inquirer, critical thinker, innovator, and reflective individual. Each component stage of the model is closely aligned with modern educational paradigms-constructivist and competency-based approaches—and is aimed at enhancing the effectiveness of the learning process through their methodological foundations.

The didactic advantages of the 5I model allow it to be applied not only in general secondary education but also in the following areas:

In STEM education: It facilitates the consolidation of learners' practical knowledge and skills through interdisciplinary integration, inquiry-based learning, and the application of innovative technologies.

In medical education: It supports the development of clinical competencies by enabling inverse (backward) analysis of clinical cases, immersive learning environments (e.g., through simulations), and the formulation of diagnostic reasoning.

In vocational training: It involves learners in real production settings, encourages innovative problem-solving approaches, and enables interpretation of final outcomes, thereby reinforcing work-based learning.

In interdisciplinary projects: Through an integrated approach, learners are trained to analyze complex problems across disciplines and develop creative solutions [11].

Each phase of this model-Integration, Inversion, Innovation, Immersion, and Interpretation-is implemented in logical and methodological continuity. This ensures adherence to the principles of sequence, consistency, and effectiveness within the educational process (see Table 2).

In the next stage, the empirical effectiveness of the 5I model can be validated by applying it in educational practice through schematic modeling, algorithmization, and sample lesson scenarios. Through this process, the methodological strength of the model becomes more clearly evident, solidifying its place among modern pedagogical technologies.

Ultimately, this methodological framework enables educators to organize problem-solving activities in biology in an innovative, integrative, and competency-based manner.

Table 2

Lesson Design Scheme Based on the 5I Model

Stage	Description	Sample Activity Based on Biological Science
1. Integration	Activating students' prior knowledge by linking the topic to other disciplines.	Introduce genetics problems by connecting them to mathematics (combinatorics, probability theory). For example: "What is the probability of a dominant allele appearing in the offspring?"
2. Inversion	Applying reverse thinking: analyzing from effect to cause (deductive reasoning).	Determine the genotype from a pedigree chart by reasoning backward. For example: "If the grandchild exhibits a recessive trait, what could be the grandfather's genotype?"
3. Innovation	Using innovative technologies, apps, or virtual tools to solve the problem.	Simulate inheritance experiments using a virtual lab program and analyze the results.
4. Immersion	Placing the problem in a real-life context to immerse learners in the situation.	Case-based task: "A patient has been diagnosed with a genetic disorder. Analyze the origin and identify the risk group based on family history."
5. Interpretation	Independent analysis, conclusion, and reflection based on the solution.	The student justifies the solution to the genetic problem in written or oral form, analyzes it using scientific language, and compares it with other cases.

Each phase of the *5I model* aligns with contemporary pedagogical approaches. Specifically:

- The *integration phase* facilitates *cross-curricular learning*, enabling students to view problems within multiple disciplinary contexts, which deepens their understanding.
- The *inversion phase* incorporates elements of *enquiry-based learning*, promoting analytical thinking as students deduce causes from given outcomes.
- The *innovation phase* enhances educational engagement by introducing *digital pedagogy* and

blended learning tools, making the learning process more interactive and technology-rich.

- The *immersion phase* aligns with *contextual learning* and *case-based learning*, drawing students into solving real-life problems and making education more relevant.
- The *interpretation phase* integrates *reflective learning* and *self-assessment*, helping learners develop skills in drawing conclusions, articulating arguments, and self-evaluating their thought processes [12].

Pedagogical Advantages of Organizing Lessons Based on the 5I Model:

- Learners develop the ability to *analyze problems in broader contexts* and connect them with multiple disciplines.
- Students enhance their *critical and logical thinking skills* by integrating both *deductive and inductive reasoning*.
- Through the use of innovative tools, learners strengthen their abilities in *information processing and digital literacy*.
- They gain *real-world decision-making skills*, such as applying knowledge in clinical or professional contexts.
- Most importantly, students acquire *scientific thinking competencies*, including the ability to make independent conclusions, justify their ideas, and evaluate arguments.

These advantages, especially in complex subjects like biology, promote active learner engagement and contribute to shaping students as curious, reflective, and research-oriented individuals.

Currently, various innovative approaches are being introduced into the educational process and promoted by researchers; however, among them, the 5I, 5E, and 4C models are considered particularly significant. Table 3 presents a comparative analysis of these pedagogical approaches.

Table 3

Comparative Analysis of Modern Pedagogical Models (5I, 5E, 4C): Analytical Table

Criterion	**5I Model *(Author: Rakhmatov U.E.)***	**5E Model *(Bybee, based on constructivism)***	**4C Competencies *(21st century skills)***
Methodological basis	Developed in the national context, based on constructivist and integrative approaches	Piaget, Vygotsky constructivism, learner-centered approach	Competency-based approach, functional literacy
Stages (or components)	Integration, Inversion, Innovation, Immersion, Interpretation	Engage, Explore, Explain, Elaborate, Evaluate	Critical Thinking, Communication, Collaboration, Creativity
Didactic goal	To develop interdisciplinary and analytical-creative thinking	To direct students towards independent knowledge construction	To form universal competencies for holistic personal development
Student role	Learner as subject, active researcher, innovator	Learner as problem explorer, experimenter, inquirer	Creative thinker, team collaborator, effective communicator
Teacher role	Guide, integrator, organizer of analytical activities	Facilitator, creator of problem-based situations	Creator of conditions for developing 4C competencies
Application in biology education	Solving biological problems through	Laboratory experiments,	Applying critical thinking, teamwork, and

	integration with chemistry, physics, technology, and math (e.g., interdisciplinary research through DNA experiment)	observations, and analysis to explain biological concepts (e.g., studying cell division in stages)	creativity to solve biological problems (e.g., developing projects for ecological issues)
Alignment with competency-based approach	Fully aligned: each stage integrates 4C skills	Competencies are gradually developed, but not fully integrated into a comprehensive system	Competency-based learning is the core
Advantages	Adapted to local education, strongly enhances creative thinking and interdisciplinary integration	Scientifically validated, tested over time; ensures consistency	Develops personal and social skills essential for modern life
Limitations or needs	Requires initial teacher training	Difficult to deviate from strict sequence; less flexible	Not a pedagogical model but a framework aimed at learning outcomes

This study analyzed the effectiveness of the 5I model in the context of biology education. The findings show that the model is highly effective in transforming students from passive recipients of knowledge into active, inquisitive, and critical thinkers. Each stage of the model serves distinct didactic functions, contributing to the overall quality of the educational process:

- Integration stage allows students to connect interdisciplinary knowledge, leading to a broader, more systemic understanding. This enhances their ability to solve complex problems.
- Inversion stage activates deductive and analytical thinking, reinforcing students' logical reasoning skills.
- Innovation stage promotes the use of digital tools and modern technologies to generate and apply new knowledge, fostering creativity and innovative thinking.
- Immersion stage is grounded in real-life contexts, improving students' practical and contextual problem-solving skills.
- Interpretation stage supports independent conclusion-making and self-assessment, developing reflective abilities.

FINDINGS FROM THE TEACHER SURVEY. The results of teacher surveys indicate that the implementation of the 5I model makes the lesson process more interactive, engaging, and effective. Teachers observed notable improvements in students' active participation, independent thinking, and problem-solving abilities. Students, in turn, appreciated the opportunity to deepen their knowledge and relate learning to real-world situations.

Furthermore, it was highlighted that the 5I model is not only applicable to biology, but also adaptable to other subjects, potentially enhancing the quality of pedagogical processes across disciplines. For this reason, further research is needed to expand and refine the model.

Summary of Key Advantages of the 5I Model in Biology Education

- Transforms students from passive learners into active, exploratory, and critical thinkers;
- Each stage aligns with specific pedagogical approaches, ensuring a methodically structured learning process;
- Enhances interdisciplinary integration, encouraging the acquisition of comprehensive knowledge;
- Promotes creativity and practical skills through technology-driven and real-world-based problem-

solving;

- Fosters reflective thinking and independent decision-making skills.

Moreover, the 5I model can be successfully applied not only in genetics or specific topics within biology, but also in other branches such as ecology, microbiology, and physiology. Additionally, it holds potential for broader use in natural sciences (e.g., chemistry, physics) and social sciences, serving as an effective tool for designing integrated educational experiences.

It is therefore recommended to develop lesson scenarios, interactive learning materials, and digital resources based on the 5I model in order to expand its practical application. Organizing specialized teacher training and promoting the exchange of pedagogical practices using the model will also contribute to improving the overall quality of education.

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