EFFECTIVE TEACHING METHODOLOGY IN BIOLOGY LESSONS THROUGH THE INTEGRATION OF 4K, 5E, AND 5I MODELS

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ANNOTATION: In modern education, deep mastery of biology, fostering interdisciplinary integration, critical thinking, creative approaches, and active student engagement are of paramount importance. This article explores methods for the pedagogical integration of the 4K model (critical thinking, communication, collaboration, creativity), the 5E model (Engage, Explore, Explain, Elaborate, Evaluate), and the innovative 5I model (Integration, Inversion, Innovation, Immersion, Interpretation) in biology teaching. In particular, the 5I model introduces new perspectives into the educational process, encourages active thinking, and enables students to acquire knowledge more profoundly.

KEY WORDS: biology education, 21st-century competencies, 4K skills, 5E pedagogical model, 5I innovative model, integrated teaching methodology, interactive and modern educational approach.

INTRODUCTION

In the modern educational process, teaching biology is not limited solely to transmitting subject-specific knowledge; it also involves developing students' critical and creative thinking, enabling independent decision-making in problem situations, understanding interdisciplinary connections, and cultivating practical skills. Such requirements necessitate that teachers move beyond traditional approaches and implement new methods and technologies. Currently, globally recognized pedagogical approaches-namely the 4K competencies (critical thinking, creativity, communication, and collaboration), the 5E model (Engage, Explore, Explain, Elaborate, Evaluate), and particularly the innovative 5I model (Integration, Inversion, Innovation, Immersion, Interpretation)-serve to enhance the effectiveness of biology instruction at the school level.

The 5I model, first proposed by Associate Professor Uchkun Ergashevich Rakhmatov, actively engages students in the learning process, strengthens interdisciplinary connections, and fosters innovative thinking. Moreover, this approach provides an opportunity for students to acquire biology knowledge in a deeper and more systematic manner.

Main Section. In the modern educational process, developing 21st-century skills in students is considered one of the primary objectives. From this perspective, the 4K competencies-critical thinking, creativity, communication, and collaboration-hold particular importance in teaching biology [1; pp. 44-102].

Critical Thinking. Analyzing biological information, identifying problems, and drawing conclusions from experimental results foster critical thinking in students. For example, studying the complexities of genetic information transfer during cell division allows students to gain a deeper understanding of cause-and-effect relationships. This approach teaches them to view biological problems from multiple perspectives [2; pp. 17-23].

Creativity. In biology lessons, students should be given the opportunity to develop new ideas, models, or solutions based on their own experiences. For instance, assigning tasks to create innovative bio-projects addressing ecological problems can enhance creativity. This method not only makes lessons more engaging but also reveals the connections between scientific knowledge and real-life applications [3; pp. 55-79].

Communication. During group work, laboratory activities, or discussions of biological problems, students learn to present their results both orally and in writing. In particular, explaining complex biological concepts to classmates strengthens their ability to express ideas logically and clearly [4; pp. 83-91].

Collaboration. Biological research often requires teamwork. Therefore, it is important to train students to work in small groups and divide tasks effectively. For example, when studying cell structure, each group member can be assigned a specific component (cytoplasm, nucleus, organelles) and then collaboratively create a comprehensive model, fostering teamwork skills [5; pp. 241-243].

Integrating the 4K competencies into biology education increases student engagement and transforms them from passive knowledge recipients into active participants in knowledge creation. This approach enables students to analyze real-life problems using biological concepts, develop ecological awareness, and enhance their scientific worldview [6; pp. 8-13].

In modern pedagogy, the 5E model, based on a constructivist approach, enables the organization of the learning process around active student engagement. Developed by Bybee and colleagues in 1987, this model proposes a step-by-step instructional system: Engage, Explore, Explain, Elaborate, and Evaluate [7]. In biology lessons, the 5E model is particularly suitable for fostering scientific thinking, acquiring knowledge through experimentation, and developing the ability to apply it in real-life situations.

Engage. At the introduction stage, it is crucial to capture students' attention and present a relevant, real-world problem. For example, questions such as "Why do some antibiotics fail to work?" stimulate curiosity and motivate students to learn [8; pp. 110-116]. At this stage, existing knowledge is assessed, and students are prepared for the new topic.

Explore. In this phase, students conduct independent or group experiments, make observations, and collect data. For instance, in studying photosynthesis, students may observe oxygen release under plant leaves through practical experiments. They propose hypotheses, test them, and refine their understanding based on observations.

Explain. During this stage, students articulate their observations and experimental results, while the teacher generalizes and clarifies scientific concepts. For example, when explaining plant movement in response to light, students provide their reasoning, and the teacher supplements it with scientific evidence.

Elaborate. Knowledge acquired is applied in new contexts. For example, students studying the cardiovascular system may observe the effects of physical exercise on heart activity or develop a project on a healthy lifestyle. This approach deepens understanding by encouraging application beyond rote memorization [9; pp. 42-44].

Evaluate. At the conclusion of the lesson, students' knowledge, analytical skills, and reasoning abilities are assessed. Evaluation can be carried out not only through tests but also via portfolios, presentations, or project defenses, ensuring comprehensive student development [10; pp. 7-74].

The 5E model transforms students from passive recipients of information into active knowledge creators. In biology education, applying this model helps students develop skills in problem identification, hypothesis formulation, observation, analysis, and independent conclusion-drawing, thus bridging the gap between memorization and practical application.

Innovative approaches play a crucial role in enhancing the effectiveness of the learning process. In this context, the 5I model used in biology education stands out due to its comprehensive approach. Developed by PhD in pedagogy, Associate Professor Uchkun Ergashevich Rakhmatov, this model is aimed at fostering deep understanding of biology, as well as developing students' analytical and creative thinking skills [11; pp. 78-92].

The 5I model consists of five key stages:

1. Integration. At this stage, connections are established between different branches of biology (e.g., genetics and ecology) or with other disciplines (e.g., physics, computer science, geography). For example, studying DNA structure through computer modeling combines knowledge from biology and informatics. This integrative approach develops interdisciplinary thinking and enhances the ability to analyze complex problems.

2. Inversion. In this stage, problems are solved in a non-traditional, reverse sequence. For instance, students may first be given a result (e.g., symptoms of a disease) and then asked to determine the cause (e.g., genetic mutation or environmental factor). This approach strengthens critical thinking and the ability

to identify cause-and-effect relationships.

3. Innovation. New technologies and methods are applied at this stage. For example, AR/VR technologies can be used to visualize cellular processes or conduct virtual laboratory experiments. This not only develops students' digital literacy but also familiarizes them with the modern scientific research environment.

4. Immersion. This stage involves "immersing" students in the biological environment under study. This can be achieved through laboratory experiments, field trips, or ecological monitoring activities. Learning through experience not only consolidates knowledge but also fosters an emotional connection to the subject matter.

5. Interpretation. At the final stage, students independently draw conclusions based on their observations and experiments, analyze results, and engage in scientific reasoning. For example, students can develop recommendations for their local area based on ecological monitoring data. This stage cultivates deep knowledge, critical thinking, and reflective analytical skills [12; pp. 9-15].

Each stage of the 5I model serves to develop different competencies in students. The **Integration** stage fosters interdisciplinary analysis and a comprehensive approach to complex problems. The **Inversion** stage enhances critical thinking and strengthens cause-and-effect reasoning skills. The **Innovation** stage promotes digital literacy and encourages creative approaches. The **Immersion** stage facilitates practical engagement and emotional connection to the subject. Finally, the **Interpretation** stage develops independent thinking, scientific analysis, and the ability to draw well-founded conclusions.

The integrated application of the 4K, 5E, and 5I models in biology education significantly enhances the effectiveness of the learning process and thoroughly prepares students for future scientific and professional activities. The core principles of this approach are described as follows.

The **4K model** is aimed at developing 21st-century competencies in students, emphasizing critical thinking, creativity, communication, and collaboration. Through these competencies, the student evolves not merely as a recipient of knowledge but as an active participant and problem solver. The teacher assumes the role of a coordinator and facilitator, guiding the process and helping identify challenges.

The **5E model** supports the learning process by basing it on the student's active experience. The **Engage** stage prepares students for the lesson, while the **Explore** and **Explain** stages allow them to conduct experiments independently and explain their findings. The **Elaborate** stage directs students to apply acquired knowledge to real-life situations, and **Evaluate** enables assessment not only of outcomes but also of the learning process. This model encourages active participation and fosters scientific reasoning.

The **5I model** ensures an integrated, innovative, and reflective approach. The **Integration** stage reveals interdisciplinary connections; **Inversion** strengthens reverse reasoning and cause-and-effect analysis; **Innovation** develops students' digital literacy and creativity; **Immersion** facilitates deep learning through practical engagement and emotional involvement; and **Interpretation** cultivates independent thinking, analytical skills, and the ability to draw conclusions.

By combining these three models, the learning process is structured as a three-tiered system: **4K** develops personal and social competencies; **5E** provides a step-by-step instructional framework; and **5I** enables deep knowledge acquisition and the application of innovative approaches. This integration enhances interdisciplinary thinking, equips students with scientific observation and analytical skills, and promotes creativity and practical activity. Additionally, assessment focuses not only on outcomes but also on students' development throughout the learning process, ensuring comprehensive preparation for future scientific and professional endeavors.

The integration of the 4K, 5E, and 5I models in biology education directs students toward deep, active, and systematic learning. The complementary nature of these approaches enhances the effectiveness of each stage of the educational process and develops students' skills not only in memorizing knowledge but also in analyzing, applying, and creatively using it. As an example, consider an integrated lesson on the topic of the **"Immune System."**

Within the framework of the **4K model**, students work actively in groups, analyze family vaccination

experiences, and generate creative ideas through questions such as, “What would happen if the human immune system did not function?” Students freely express their opinions in groups, thus developing communication skills.

The **5E model** structures the lesson and promotes active learning. During the **Engage** phase, students’ attention is drawn through questions like, “Why do some diseases not recur after infection?” In the **Explore** phase, students independently study components such as lymph nodes and white blood cells using interactive models. In the **Explain** phase, the teacher provides a scientific explanation of T-cell and antibody functions. During **Elaborate**, students extend their knowledge by analyzing the COVID-19 vaccine from biological and social perspectives. Finally, in the **Evaluate** phase, students’ knowledge is assessed through Q&A sessions, group tests, and small projects.

The **5I model** introduces depth and innovation to the lesson. In the **Integration** phase, biology, history, and computer science are combined, for example, by studying the history of vaccination alongside interactive models. In the **Inversion** phase, students are given a disease scenario and must determine how the immune system fails, strengthening critical thinking and cause-and-effect reasoning. During the **Innovation** phase, 3D models and AR applications are used for lymphatic system simulations. In the **Immersion** phase, students visit health centers or meet with medical volunteers to gain practical experience. In the final **Interpretation** phase, students create a video promoting vaccination based on their observations and analyses.

The result of this integrated approach is highly active student participation, significantly increased biological literacy, and enhanced social engagement through group work and presentations. Students go beyond memorization, developing skills in analysis, real-life application, and generating new ideas. Integration transforms students from passive listeners into active participants, strengthens interdisciplinary thinking and technological literacy, and increases external motivation, thereby thoroughly preparing them for future scientific and professional activities.

Conclusion. In modern biology education, the integrated application of the 4K (Critical Thinking, Creativity, Communication, Collaboration), 5E (Engage, Explore, Explain, Elaborate, Evaluate), and 5I (Integration, Inversion, Innovation, Immersion, Interpretation) pedagogical models significantly increases the effectiveness of the educational process. This approach transforms students from passive recipients of knowledge into active, critical, and creative thinkers capable of making independent decisions in problem-solving situations.

The **4K competencies** develop communication, collaboration, and creativity skills required in modern social and scientific contexts. The **5E model** organizes learning step by step, enabling a deep understanding of knowledge. The **5I model** ensures deep learning through interdisciplinary integration, reverse reasoning, the application of innovative technologies, practical experience, and independent scientific analysis.

When applied together, these models make biology lessons not only engaging and interactive but also enhance students’ scientific literacy, critical thinking, and creative problem-solving skills, thoroughly preparing them for future professional and scientific activities. Therefore, the use of the 4K, 5E, and 5I approaches in school biology education is methodologically effective and highly relevant.

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