Methodology for Developing Students' Ecological Competence through an Integrative Pedagogical Model in Biology and Microbiology Education

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ABSTRACT

This article presents a didactic model aimed at enhancing students' ecological competence through the teaching of biology and microbiology within the undergraduate program "Ecology and Environmental Protection." The model is based on interdisciplinary integration, developmental education, and a value-oriented approach. It emphasizes meaning-making through student-centered learning principles such as personal experience, reflection, and collaborative learning. The proposed methodology is suitable for technical higher education institutions and contributes to the formation of ecological awareness and sustainable thinking.

Keywords: Ecological competence, integrative pedagogy, interdisciplinary education, biology and microbiology, sustainable education, didactic model.

Introduction. In the 21st century, addressing ecological challenges requires not only scientific knowledge but also moral responsibility. Ecological competence encompasses not just the understanding of ecological facts, but also the ability to apply them in real-life contexts, make conscious decisions, and act sustainably. This article analyzes the potential for developing students' ecological competence through an integrative pedagogical model grounded in biology and microbiology. The discipline of "Biology and Microbiology," with its relevance to economics and education, supports the development of professional competence based on ideological concepts such as co-evolution, biocentrism, and bioethics. Modern bioecological education is simultaneously a factor in civilizational progress and global security. Therefore, it deserves special attention in the 21st century. Time determines the most critical fields of knowledge that influence societal development. In our era, this role belongs to biology and ecology. Studying the trends of development and the ways to address complex socio-economic, ecological, and educational issues through biology and microbiology leads to the conclusion that the primary mission of bioecological education is to contribute to the preservation of life on Earth—achievable only through the cultivation of biological and ecological thinking.

Theoretical foundations. The integrative approach is based on constructivist learning theory, which posits that knowledge is formed through active assimilation. This approach aligns with the humanistic paradigm, transitioning from the concept of an "educated person" to that of a "cultured individual." The model connects biological sciences with humanities, ethics, and social sciences to create a holistic educational experience. Contemporary pedagogical conditions are classified into three main groups: organizational-pedagogical, psychological-pedagogical, and didactic conditions.

Organizational-Pedagogical Conditions. Some researchers define this group as the essential resources for implementing educational activities. Others argue that these conditions encompass not only the material resources provided by educational institutions but also the interactions among participants and the organizational forms of education. The primary function of this group is to establish a set of pedagogical interventions that ensure goal-oriented and planned management of the educational process. Thus, these conditions can be viewed as the procedural aspect of the pedagogical system.

Psychological-Pedagogical Conditions. These conditions aim to foster interpersonal relationships among participants in the educational process, thereby enhancing its effectiveness. Their main role is to facilitate pedagogical interactions that consider students' individual characteristics and educational needs. Consequently, psychological-pedagogical conditions represent the learner-centered aspect of the pedagogical system.

Didactic Conditions. Didactic conditions involve selecting and implementing available educational resources in alignment with instructional goals. Their primary function is to shape the content of education and deliver it through appropriate instructional formats. This includes the use of effective methods, teaching techniques, and various didactic tools.

It is noteworthy that the three groups of pedagogical conditions—organizational-pedagogical, psychological-pedagogical, and didactic—are considered internal pedagogical conditions, as they can be modified and improved.

Model Description. The didactic system developed for teaching biology and microbiology is based on the following principles:

- **Interdisciplinary integration**: studying biological knowledge within cultural, ethical, and social contexts
- **Developmental principle**: fostering personal growth and critical thinking
- **Free choice**: allowing students to define their own educational goals
- **Effectiveness principle**: evaluating educational outcomes through personal transformation
- **Facilitation principle**: creating conditions for self-directed learning and reflection

Students integrate educational content independently, transforming knowledge into personal meaning through the synthesis of emotions, concepts, and experiences.

Practical Guide: Laboratory Integration. Within the framework of the model, students conduct a laboratory exercise involving the preparation of homogenates from plant tissues. This practical session includes:

- Preserving leaf tissue on ice and mechanical grinding
- Mixing with buffer solution
- Homogenization and centrifugation steps
- Microscopic analysis of organelles

This process not only reinforces biological concepts but also deepens students' understanding of the complexity and fragility of ecological systems.

Results. Students participating in laboratory activities:

- Demonstrated conscious attitudes toward ecological issues
- Developed the ability to analyze biological processes within ecological contexts
- Increased interest and motivation regarding sustainability topics

Students' self-defined goals included understanding biological diversity.

Conceptual framework. The didactic teaching model is based on a conceptual system that incorporates various types and technologies of integration aimed at developing ecological competence. It promotes:

- A holistic worldview
- Value-semantic orientations characterized by ethical attitudes toward nature, human life, health, and cultural achievements

- Systems thinking skills
- Application of acquired knowledge and methods
- Effective adaptation to changing life conditions

In the integrative course on ecological competence development, systematic knowledge is ecological in nature and serves as a supportive foundation by merging students' personal experiences with knowledge from other disciplines. This creates a unified scientific and socio-cultural context and a holistic educational environment, manifesting as a cultural model.

The holistic educational space, as part of the social domain, initiates meaning-making processes that lead to personal growth and self-development. The richer and more diverse this space is, and the more fully individuals engage with it, the more successful and dynamic the formation of integrative semantic self-regulation and self-development becomes.

Pedagogical considerations. The didactic system model accounts for age, professional interests, needs, students' personal experiences, and psychophysiological characteristics related to different types of thinking. It supports various activities, relationships, and semantic reflection. All of these contribute to the creation of deep personal meanings in learning, allowing students to enter an integrative educational system at a personal level.

The structure of integrative sessions aligns with the goals of integrative ecology and the criteria for developing ecological competence. These sessions foster situational experience in applying knowledge through creative activity, generating educational products (new knowledge with personal or cultural novelty), enhancing cognitive curiosity, thinking ability, meta-disciplinary skills, positive self-awareness, and value-semantic orientations.

The content-rich didactic model of integrative teaching reflects the educational process as an integral part of social life and supports the formation of a holistic individual with ecological competence within the higher education system.

Discussion. The integrative pedagogical model expands the boundaries of traditional disciplines. Students examine ecological issues from multiple perspectives. By incorporating ethical and cultural dimensions into biological education, sustainable thinking is cultivated. Laboratory activities connect theoretical knowledge with practical experience.

Conclusion. Implementing an integrative pedagogical model in biology and microbiology education is an effective methodology for developing ecological competence. This approach supports interdisciplinary thinking, personal growth, and sustainable action. Students in experimental groups consistently demonstrated higher levels of ecological competence compared to control groups, confirming the effectiveness of the proposed methodology and model. The model is applicable across various educational institutions and contributes to the training of environmentally conscious professionals.

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