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# New model and paradigms of complex formation of competencies in biological disciplines

Zhadyra Kabatayeva[1*], Kulzhakhan Bakirova[2], Zukhra Bagimbayeva[3], Gulnara Kulenova[4], Balzhan Missinova[5]

[1]*Department of Biology, Sarsen Amanzholov University of East Kazakhstan, Ust-Kamenogorsk, Kazakhstan.*
[2]*Institute of Natural Sciences and Geography, Abai Kazakh National Pedagogical University, Almaty, Kazakhstan.*
[3,5]*Department of Biology, Sarsen Amanzholov University of East Kazakhstan, Ust-Kamenogorsk, Kazakhstan.*
[4]*Higher School of Pedagogy, Sarsen Amanzholov University of East Kazakhstan, Ust-Kamenogorsk, Kazakhstan.*

Corresponding author: Zhadyra Kabatayeva (*Email: anubayev@mail.ru*)

## Abstract

In this paper, we present a new interpretation of the principles of an integrated approach to the formation of professional competencies of students majoring in biology. The theoretical principles of cognitive multilayering (CMP), dynamic interdisciplinarity (DIF), and cognitive-digital synthesis (CDC) are formulated. Problematic retraction (PIT) and engagement shift (EST) are discussed. The methodological basis for the need to transform from fragmentary pedagogical strategies to the systemic integration of interdisciplinary, cognitive, digital, and project-research components of educational processing has been updated. The methodological foundations of the integrated approach, including the activity paradigm, constructivism, competence model, and elements of digital pedagogy, have been revised. The author's model of the integrated approach, which takes into account the challenges of the modern educational environment and focuses on the development of professional thinking, research, and digital skills of future specialists, is interpreted. The pedagogical productivity of this approach for the formation of holistic and adaptive educational trajectories in natural science training in educational processing in biological disciplines is theoretically substantiated.

**Keywords:** Biological education, cognitive activity, digital educational environment, digitalization, higher education, integrated approach, interdisciplinarity, pedagogical model, professional competencies, student subjectivity.

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## 1. Introduction

The old and traditional system of higher education has lost its relevance. Today, new modern paradigms of educational relations are coming into force. These methods are not based solely on the mechanical transfer and retransmission of knowledge. However, there is a new educational and cognitive landscape of systemic, critical, and productive thinking for future specialists and professionals. This challenge of modern knowledge is manifested predominantly in the training of students and naturalists. In particular, future biologists, whose professional activity requires a synthesis of theoretical foundations, research skills, and technological competencies, are needed.

In this context, an integrated approach to organizing educational processes acts not merely as a pedagogical methodology in the narrow sense but rather as a holistic (integrated and additive) strategy for designing, constructing, and assessing the training of a specialist [1]. This new educational strategy is localized to the integration of several key components: content-disciplinary unity, cognitive and meta-subject flexibility, digital transformation of the learning environment, and project-based research activities of students. Complexity, in this case, is interpreted not as a simple sum of elements but rather as a qualitatively new system and structure of educational processes, based on systemic and coherent connections between different disciplines, methods, levels of involvement, and contexts of knowledge utilization and development.

Our interpretation of the principles of the integrated approach is based on the classical constructions of pedagogical knowledge: the concepts of activity-based and constructivist learning, cognitive theory, and competence-based and synergetic approaches [2, 3]. It involves not only identifying and describing the components of integrated learning but also developing a model of their interrelationship that can adapt to changing educational conditions and tasks. Another thing is that this pedagogical foundation requires modernization.

Here, we pay attention to the axiological and pragmatic vectors of the integrated approach. In this context, the student is considered not only an object of the assimilation of information but also a subject of meaning-making, reflection and scientific action. The inclusion of digital tools, simulation laboratories, project formats and interdisciplinary research not only complements traditional pedagogical means but also qualitatively constructs a new structure of educational interaction, increasing the level of autonomy, motivation and responsibility of the student.

Thus, the integrated approach combines elements of innovative pedagogical technologies aimed at the comprehensive development of the student's personality. To verify the effectiveness and efficiency of the integrated approach, a comparative analysis of the traditional and integrated approaches in education can be interpreted [4]. In particular, this interpretation can be visualized and updated in the form of the following comparative table:

**Table 1.**
Comparison of traditional and integrated approaches in specialized teaching

| Aspect | Traditional approach | Integrated approach |
|---|---|---|
| Purpose of the training | Relaying knowledge, cultivating skills and abilities | Updating competencies, critical thinking, ability to self-motivate and self-learn |
| The role of the teacher | Dominant source and analyzer of information, controller of educational processing | Scaffolder, tutor, facilitator, knowledge manager, attractor of self-learning and self-knowledge |
| The role of the student | Passive recipient of knowledge, subject of instructional execution | The main agent of educational processing, the modulator of knowledge |
| Teaching methods | Lectures, explanations, memorization, seminars, reproductive exercises | Collaboration, project work, problem-based learning, research, discussions |
| Contents of the training | Structured by disciplines. With an emphasis on theory | Coherent knowledge connections, integration of interdisciplinary knowledge, relevance of content, and intellectual activation |
| Evaluation | Tests, exams that check memorization and reproduction of information | Project assessment, portfolio, self-assessment, taking into account the process and outcome of learning |
| Use of technology | Limited use of ICT, primarily for information transfer | Active use of digital technologies for modeling, data analysis, communication |
| Motivation of students | External motivation: grades, teacher's requirements | Intrinsic motivation: interest in research, personal significance of tasks |
| Communication | One-way: from teacher to student | Multilateral: interaction between students, with the teacher, with external experts |
| Flexibility of learning | Rigid structure, poor adaptation to individual needs | Individualization and personalization of learning, adaptation to the interests and abilities of students |

Thus, this table interprets the dominant differences between the traditional and integrated approaches in education. A priori, we actualize the advantages of integrating techniques and methods in the context of the modern educational process.

Thus, the purpose of this work is a theoretical and conceptual interpretation of the integrated approach as a methodological basis for the formation of the professional competencies of biology students. As part of the analysis, we

somewhat clarified the conceptual apparatus and defined the structural components and functional connections of the integrated approach. In addition, we structured its potential in the context of training a new generation of specialists.
Accordingly, we defined the outline tasks of our research:

1. Analysis of the methodological foundations of the integrated approach in the context of modern pedagogical, cognitive and information theories;
2. Definition of key components of an integrated approach: substantive, methodological, digital and cognitive value;
3. Research into the didactic potential of interdisciplinary and digital integration in biological education;
4. Construction of theoretical and conceptual models of an integrated approach aimed at developing the professional competencies of biology students;
5. Justification of teaching conditions for the implementation of this approach in a digital educational environment.

Thus, if the educational processing of biology students is organized on the basis of a systemically structured complex approach, including the integration of interdisciplinary knowledge, cognitive strategies, digital technologies and project-research activities, then this will clearly and directly ensure a greater degree of formation of professional competencies. Most importantly, it allows training to adapt to the challenges of the digital era, promoting the development of the subjective position and self-motivation of students in the process of cognition and professionalization.
In this work, the scientific novelty of the research is interpreted and updated in the following provisions:

- Conceptualization of an integrated approach as a modern pedagogical system in which cognitive, content, digital and activity components are localized into a holistic model for training biology students.

The structure of the integrated approach has four main definitions:

- Cognitive value level;
- Interdisciplinary module;
- Digital instrumental component;
- Meta-reflexive accompaniment.

The analysis and synthesis of paradigms and definitions of the complex (additive) methodology will allow us to form a framework of principles that unites the methodological foundations of the activity approach, constructivism, competence paradigm, and digital pedagogy in the context of natural science education in the field of biology. In particular, we touched upon the heuristic function of the complex approach as a mechanism for flexible adaptation of educational processes to the rapidly changing conditions of the digital environment and the demands of modern science.

In general, in this work, we propose an additive model of dominant principles for the formation of the professional competencies of biology students. In problem-oriented tasks, digital simulations and interdisciplinary project trajectories play a key role.

## 2. Literature Review

The number of works in the field of integrated learning is constantly increasing. This reflects the extreme relevance of this topic. We can also note a permanent increase in scientific publications in the field of biological disciplines (Figure 1). Since 2016, the number of publications on this topic has increased from 41,000 to 87,000 in 2024.

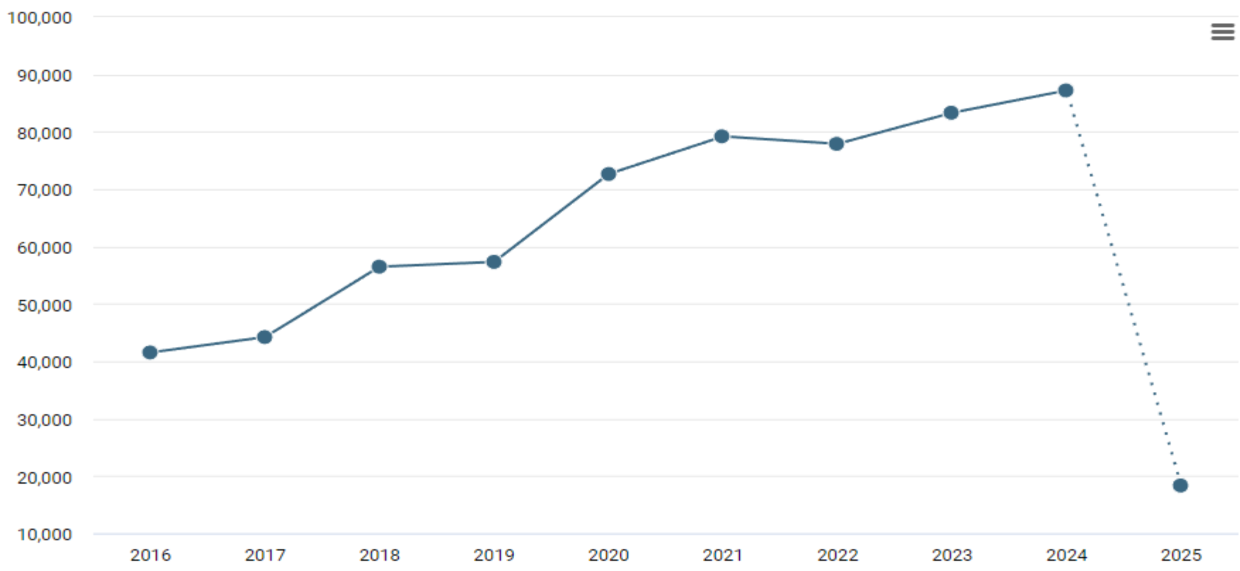


**Figure 1.**
Dynamics of the growth of publications on integrated education in biology (according to Dimensions.ai).

We can also note a significant increase in the number of citations in the biological field for this period: from 930,000 in 2016 to 3,200,000 citations in 2024. This circumstance indicates a significant and dynamic actualization of the topic of comprehensive education in biological disciplines (Figure 2).

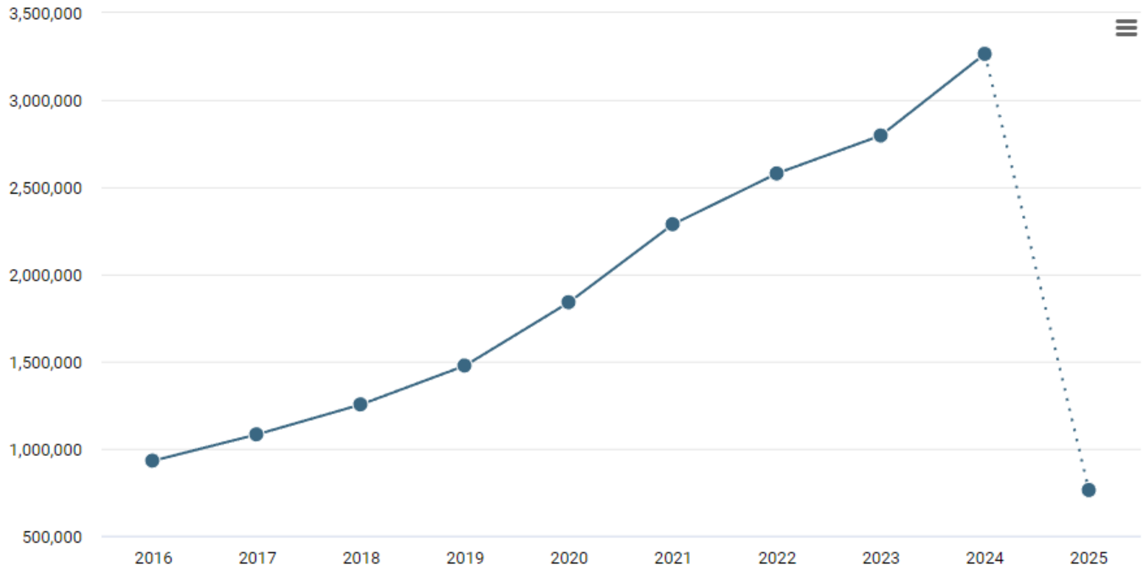


**Figure 2.**
Dynamics of citation growth for comprehensive education in biology (according to Dimensions.ai)

Thus, the topic of integration as a methodological basis for modern education is actualized through the reduction of differentiation of scientific knowledge by discipline [5, 6]. This is especially relevant for areas in the STEM field. Notably, integrated STEM education is an excellent approach for improving the abilities and skills of students needed in the modern era [7].

Notably, biological disciplines are complex enough to be taught in schools and universities [8]. Therefore, the modernization of new educational techniques and methods is extremely important in teaching biology at all educational levels. This modernization should be associated with improving cognitive skills and academic performance, developing interest, motivating students and ensuring that students better understand the content of the lessons.

In the context of modernization, practical strategies such as project-based learning, experiential learning, and technology-enhanced learning have been proposed to enhance student engagement and cognitive ability [9]. Integrated biology lessons that bring together knowledge from different subjects to understand complex concepts and apply them practically through a variety of seminar and lesson options are also discussed [10]. In this context, through integration, students are able to connect the dots between disparate subjects and concepts, creating a more holistic and comprehensive learning experience [11].

Particular emphasis is placed on the use of problem-based learning modules in biology. These modules offer flexibility and focus on the core content of the biology topic, character development and student competencies [12]. Moreover, the effectiveness of integrated biology teaching is well interpreted through a comparative analysis of experimental and control groups of students. In particular, compared with traditional teaching strategies, experimental methods significantly improve the efficiency and effectiveness of students' acquisition of biological knowledge [13].

Innovative models of integrated teaching based on digital tools such as PPTs, LCD and smartphones are also being actively developed to improve the efficiency, benefit and meaning of biology teaching [14]. Integrated digital technologies make it possible to use biology with a research model. This provides the possibility of more effective learning by combining a biological subject and its digital model.

Overall, as the literature review shows, the complex education landscape continues to evolve rapidly. It is imperative for educators to stay current with innovative strategies and approaches to effectively prepare students for the complexities of the 21st century [15, 16].

## 3. Materials and Methods

The Dimensions.ai search platform was used to search, select and analyze literary sources on the topic of an integrated approach to teaching biological disciplines.

In our analysis and synthesis, we proceeded from the interdisciplinarity of methodological approaches, ensuring a systematic and in-depth understanding of the integrated approach as a pedagogical phenomenon.

In our study, we relied on the following methods:

- Analysis and synthesis of scientific and pedagogical literature to identify relevant approaches to organizing the educational process and models for training specialists in the context of digital transformation;
- Modeling as the construction of a theoretical model of an integrated approach, including its components, principles and mechanisms of implementation;
- Typological and structural analysis as the identification of elements, levels and functions of an integrated approach in the educational system;

- With comparative analysis as a correlation of the integrated approach with traditional models of training to substantiate its advantages and features;
- A systemic approach as an interpretation of a comprehensive approach as a holistic pedagogical system with internal logic and dynamics.

The technology of the theoretical approach was based on:

- The activity-based approach as a paradigm that considers education in terms of subjective activity and the transformation of personal experience through educational activities;
- To a competency-based approach, ensuring an emphasis on educational results in the form of integral personality characteristics;
- And an integrative-synergetic approach for theoretical analysis of the interaction of elements of the educational environment, disciplines and digital tools as a system with emergent properties;
- To constructivism and connectivism as cognitive foundations that emphasize the role of subjective meaning, self-organization and digital networks in the construction of knowledge;
- Digital pedagogy as a modern framework for analyzing the influence of the digital environment on the forms, mechanisms and results of learning.

The object of the study was the process of developing the professional competencies of biology students in the higher education system.

The subject of the study was the methodological, substantive and organizational-pedagogical foundations of an integrated approach as an integrative strategy for training biologists.

The digitalization of the educational space, the interdisciplinarity of natural science knowledge and the development of innovations in the field of STEM education were interpreted as the context of the study.

Since this study is theoretical and methodological in nature, it is not aimed at empirically testing the model in a specific educational environment. However, the proposed foundations can be used as a theoretical basis for subsequent experimental and applied research.

## 4. Results

Thus, with a priori probability, we believe that the effectiveness and efficiency of complex educational processing is interpreted through the parallel interaction and correlation of the following attributes (Figure 3):

- An activity-based approach that reveals the formation of competencies through the active cognitive and research activities of students;
- A competence-based paradigm that ensures the target orientation of the educational process toward professional and meta-subject results;
- An integrative-synergetic approach that allows the modeling of complex educational systems with nonlinear development logic;
- Constructivist cognitive theories that actualize the individual nature of understanding and internalization of knowledge;
- Digital pedagogy, which actualizes the use of digital and simulation tools in the formation of flexible educational trajectories.

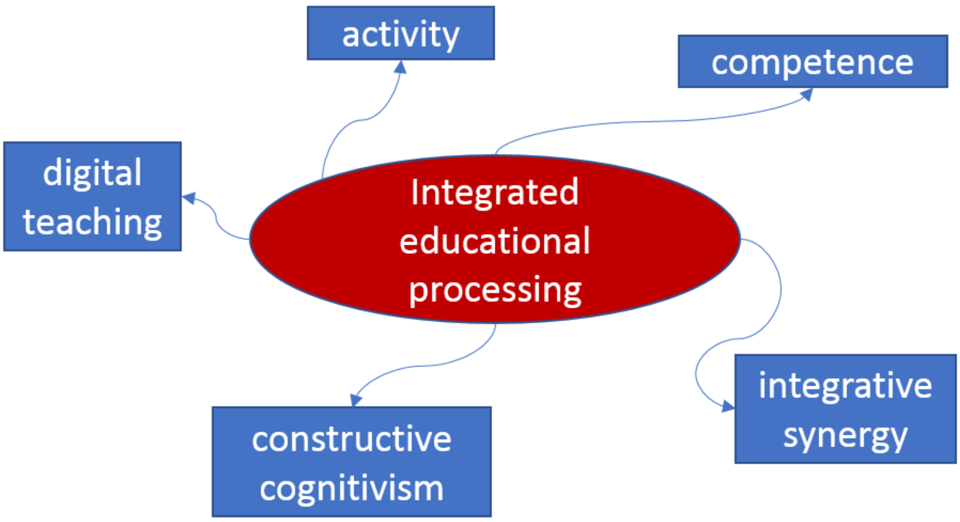


**Figure 3.**
Five attributes of complex educational processing

We interpret these attributes to form the principles of an integrated approach as a systemic, flexible and adaptive educational mechanism.

First, let us formulate a level model of an integrated approach, including four interconnected levels (Figure 4):

- The cognitive value level (aimed at developing students' reflective, research and professional thinking, including awareness of the personal significance of the subject of study);
- Content-disciplinary level (implements interdisciplinary integration of academic courses (botany, zoology, molecular biology, ecology, etc.), contributing to the formation of a holistic natural science worldview);
- Digital instrument level (includes the use of simulators, virtual laboratories, interactive platforms and digital analytical tools that enhance both knowledge visualization and research activity);
- Project-activity level (ensures the inclusion of students in problem-oriented, research and project-based learning formats that contribute to the formation of sustainable professional competencies).

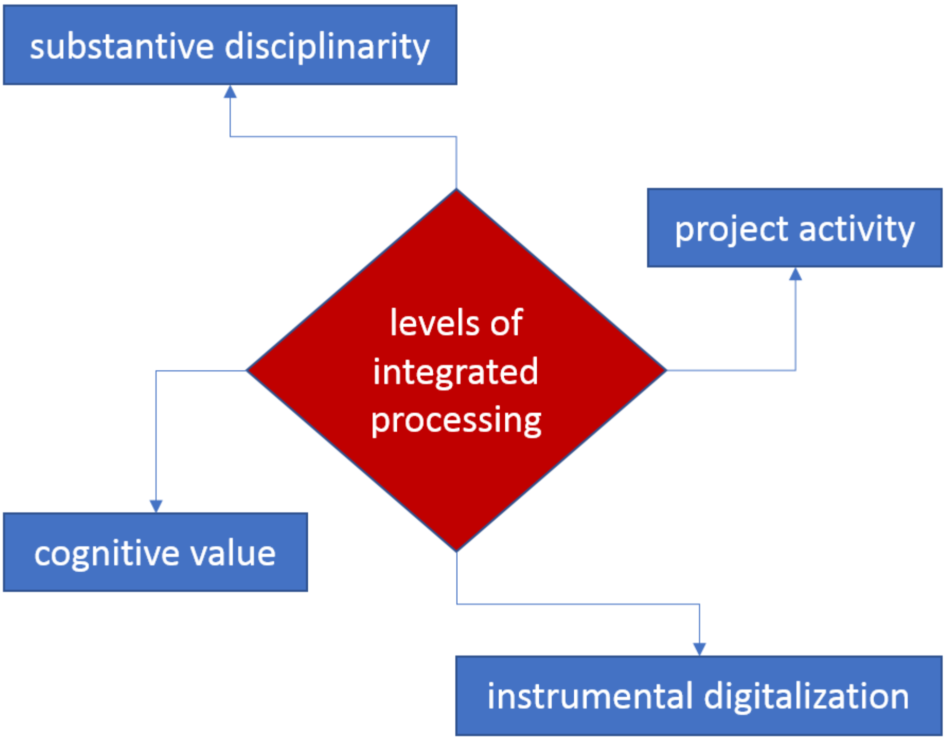


**Figure 4.**
Four levels of complex educational processing

On the basis of the attributes and levels of complex educational processing, we can postulate the following principles (Figure 5):

- Principle cognitive multilayer (cognitive multilayer principle, CMP);
- Principle dynamic interdisciplinarity (Dynamic Interdisciplinary Framework, DIF);
- Principle cognitive digital synthesis (cognitive-digital convergence, CDC);
- The principle of problematic retraction (problem immersion theory (PIT));
- Principle Engagement Shift Theory (EST)

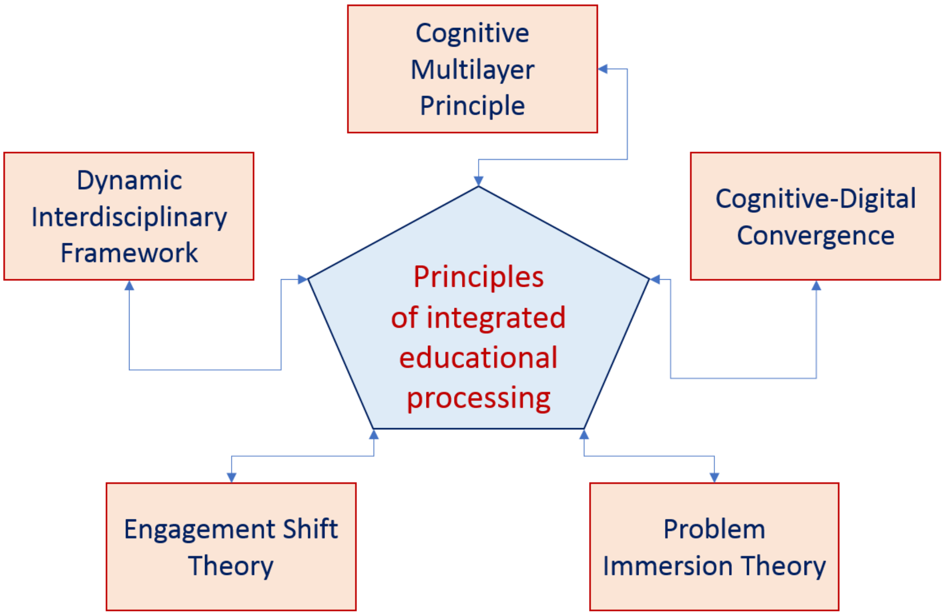


**Figure 5.**
Five dominant principles of complex educational processing

The postulated principles reveal the essential content of the integrated approach of educational processing in biological areas. These principles significantly expand the existing conceptual and methodological tools of teaching science and can be used as a fundamental basis for designing innovative educational models and modules.

Let us consider the internal structure of the postulated principles.

*4.1. Principle cognitive multilayer (Cognitive Multilayer Principle, CMP)*

This principle interprets the cognitive process as a hierarchical system of cognitive layers, each of which performs a specialized function (Figure 6).

- With the sensory layer as primary perception,
- Basic cognitive recognition and categorization,
- Conceptualizes the formation of concepts and models;
- Metacognitive as awareness of ways of thinking;
- With intellectuals as productive thinkers and transdisciplinary connections.

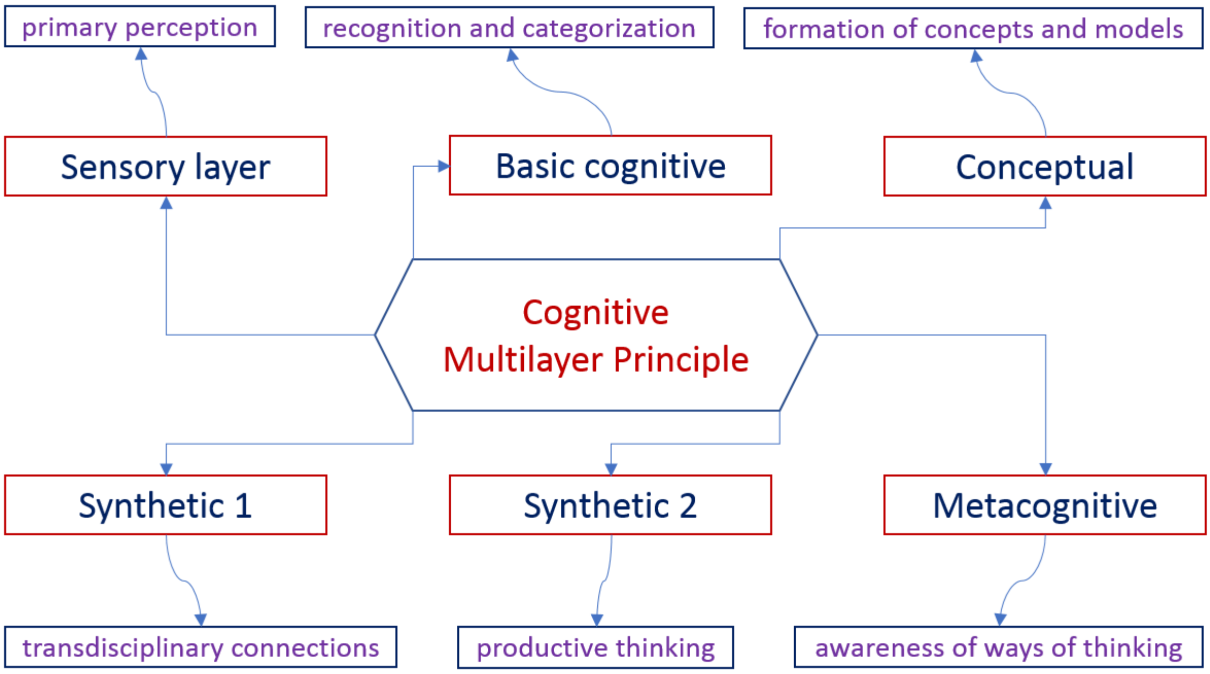


**Figure 6.**
Five dominant principles of complex educational processing

The transition or diffusion between these layers is not linear, but in the form of cognitive phase jumps. In this case, knowledge is qualitatively rebuilt. This circumstance allows for the formation of a deep, stable and adaptive cognitive structure in the student.

### *4.2. Principle of Dynamic Interdisciplinarity (Dynamic Interdisciplinary Framework, DIF)*

Under this principle, we believe that complex educational processing is a nonlinear and self-organizing process in which the interaction of disciplines generates emergent forms of knowledge that we interpret through interactions (Figure 7):

- With weak and strong connections between disciplines (from complementarity to transdisciplinary fusion);
- To cognitive-informational fields in which mutual attraction of concepts and methods occurs;
- Phase transitions, in which interdisciplinarity gives rise to new scientific fields (for example, bioinformatics, neuroethics, etc.).

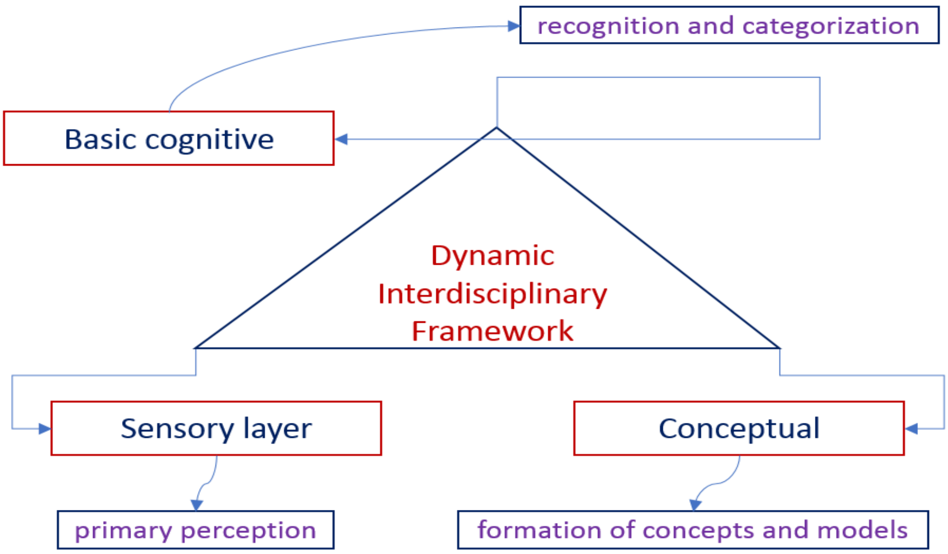


**Figure 7.**
Structure of the principle of dynamic interdisciplinarity.

Thus, the DIF proposes a method for the predictive forecasting of new areas of scientific growth on the basis of the analysis of intersection points of related and distant disciplines.

### *4.3. Principle of cognitive-digital synthesis (cognitive-digital convergence, CDC)*

According to the principle of cognitive-digital synthesis, a student's intellectual behavior is formed as a result of the coevolution of human thinking and digital systems. Here, we distinguish 5 levels of digital integration (Figure 8):

- Digital zero;
- Digital support;
- Digital complementarity;
- Cognitive integration;
- With intellectual intelligence.

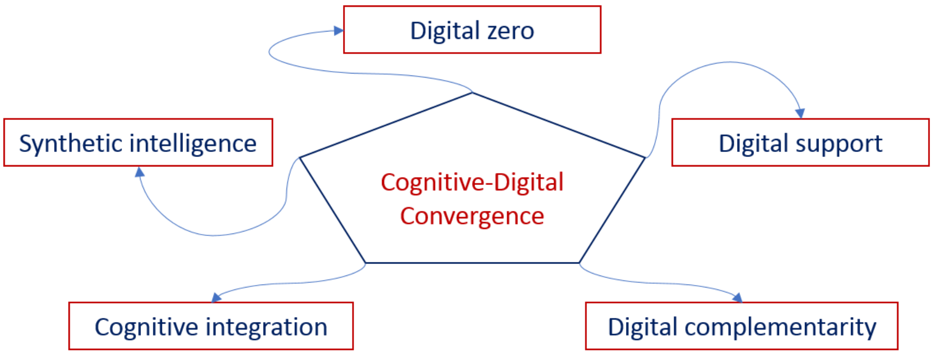


**Figure 8.**
Structure of the principle of cognitive-digital synthesis

Each level of CDC reflects the degree of involvement of digital platforms, AI, simulators and analytical environments in educational processing. At the highest level of education, the student automatically becomes a cognitive coauthor with intelligent systems.

*4.4. Principle of Problematic Retraction (Problem Immersion Theory, PIT)*

Within the framework of this theoretical principle, we propose a new interpretation of problem-oriented learning as a form of cognitive and emotional entry into a problem situation. The student does not solve the problem "from the outside" but immerses himself in the problem field as a subject of action. We distinguish four levels of involvement (Figure 9):

- And informational;
- Role-playing;
- Ethnic;
- Meta-problematic.

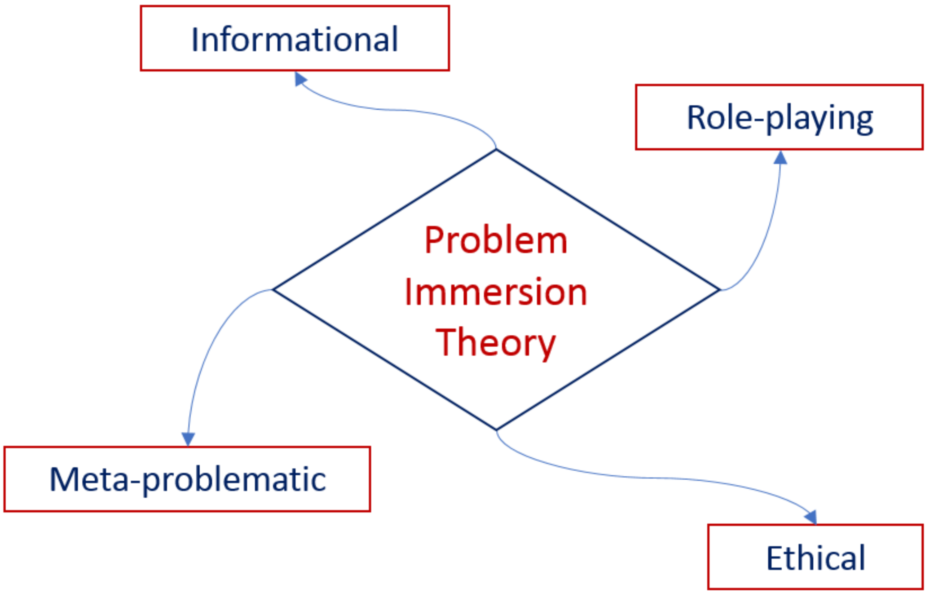


**Figure 9.**
Structure of the principle of problematic retraction

Here, we interpret the principle of problematic involvement as living a meaningful reality. The research position, scientific motivation and self-determination skills of the student in complex situations related to the mentioned specificity of biological directions are formed.

*4.5. Principle Engagement - Shift (Engagement Shift Theory, EST)*

In the context of the theoretical principle of engagement shift, the concept of active involvement is formulated not as a state but as a dynamic process of semantic shift from functional participation to existential co-authorship. In this context, the EST principle includes three levels of involvement in complex educational processing (Figure 10):

- Three vectors of involvement: cognitive, emotional, value;
- Five stages of inclusion: from detachment to the level of identification semantic inclusion;
- The principle of co-identification, according to which learning is effective only when the student identifies themselves with the content and goals of the activity.

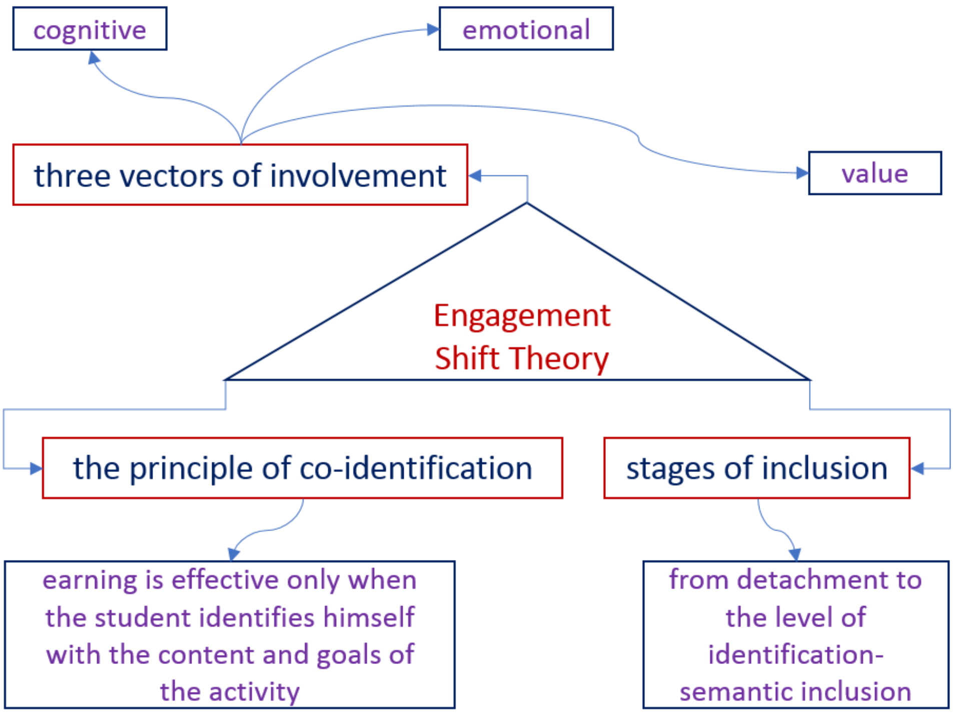


**Figure 10.**
Structure of the engagement-shift principle

Thus, the EST principle opens up prospects for the development of diagnostic and design models of pedagogical environments that are capable of sustaining students' motivational and value-based participation.

Thus, we can postulate that the following conditions are necessary for the productive implementation of the model principles of the integrated approach:

- Ensuring interdisciplinary coherence of curricula;
- Organization of a digitally rich educational environment;
- Formation of variable educational routes with elements of personalization;
- Inclusion of students in intellectually rich problematic contexts that support internal motivation and a subjective position;
- Regular methodological support for teachers, facilitating the introduction of an integrated approach into teaching practice.
- We propose that this method has potential not only for developing professional competencies but also for the following prospects:
- Restructuring the educational environment through flexible forms of organization of the educational process;
- Increasing the cognitive activity of students due to the variability of formats and tasks;
- Strengthening motivation for independent scientific activity;
- Development of students' ability for reflection and transdisciplinary thinking, which is in demand in modern scientific practice.

In general, the principles of the integrated approach we have formulated can become a promising educational strategy. This approach is capable of integrating modern requirements for biological education, enhancing both its substantive depth and its practice-oriented focus. The proposed theoretical model of principles can be used as a basis for designing educational platforms, programs, and modules for the new generation. In addition, further experimental research is needed.

## 5. Discussion

Thus, the theoretical justification of an integrated approach to training biology students is certainly not just a methodological task but a significant epistemological challenge. This is associated with rethinking the very nature of education in the context of scientific and technological turbulence. It is evident that fragmentary, discipline-limited, and reproductive classical models of training specialists in the field of biology are clearly insufficient for the formation of relevant professional and meta-subject competencies updated in the 21st century. In contrast, an integrated approach based on the attributes, levels, and principles we have proposed is capable of integrating content, methods, technologies, and cognitive mechanisms into a single integrated adaptive system.

We believe that one of the key features of the developed concept is its multilevel structure, in which the cognitive, content, digital and project components are interconnected and have functional complementarity. This nonlinear model clearly and directly corresponds to the principle of pedagogical systematicity. The presence of hierarchy, goal setting, self-regulatory mechanisms and direction directly contributes to the effective and efficient development of the student as a subject of knowledge, cognition and training.

We focused on the interdisciplinary nature of integrated learning, which is fundamentally important for biological education. Biology as a science was initially integrated into a wide network of interactions with other disciplines: chemistry, physics, ecology, mathematics, computer science, philosophy of science and medicine. Therefore, the training of a biologist requires not only the transfer and retransmission of disparate and random knowledge but also the formation of a holistic scientific worldview based on the ability for conceptual integration, the transfer of methods and flexible conceptual thinking. In this context, in particular, the principle of dynamic interdisciplinarity (DIF) is a tool for describing and designing interdisciplinary synthesis as a nonlinear and emergent process.

Principle (CMP) allows us to conceptualize the internal structure of cognition as a set of interacting layers, from sensory perception to synthetic thinking. This provides certain and additional grounds for constructing educational content depending on the depth of the cognitive processing of the content material by the student.

The issue of digitalization of the educational environment is often interpreted as a technological transformation. However, this interpretation should be considered much more deeply within the framework of an integrated approach. The principle of cognitive-digital synthesis (CDC) allows us to interpret digitalization as a process of coevolution of cognitive and computational activity. This, accordingly, leads to the formation of a new type of student thinking as distributed, algorithmically mediated and flexibly adaptable. Thus, digital tools are not external appendages but are organically integrated into the structure of an integrated approach because of their functional and didactic core.

The integration of problem-oriented learning through the principle of problem-based involvement (PIT) makes it possible to distance oneself from the functionalist interpretation of tasks and cases. By considering them as semantic fields, the student enters not to solve but to experience the educational processing itself. This fundamentally changes both the nature of motivation and the form of thinking. That is, from searching for the "right answer" to building one’s own cognitive position. Similarly, the theory of engagement shift (EST) conceptualizes involvement not as a reaction but as a transition to semantic co-identification. This is especially important in the context of the formation of the student’s subjectivity.

Notably, the updated principles are not isolated concepts. They are built into a single metaeducational framework (skeleton), which reflects a systemic redefinition of the higher education paradigm. They demonstrate internal consistency, reproducibility at different levels of the educational process (from a course to a program), and practical applicability in constructing educational trajectories for natural science areas.

Thus, our consideration hypothetically and theoretically confirms the heuristic potential of the integrated approach not only as an educational model but also as an innovative way of thinking about education in the conditions of the multidimensionality of the modern world. We see prospects for further research in the operationalization of the proposed principles and in their inclusion in programs for training biological personnel. The empirical validation of the proposed model through experimental implementation in university courses is also needed.

The systematicity and originality of the proposed principles allow us to speak about the formation of a new theoretical and pedagogical paradigm in which learning is considered a high-level cognitive-value activity that occurs in a network, simulation and digital environment.

The integrated approach appears here not as a sum of methods but as an ontological framework for education, corresponding to the post-nonclassical stage of the development of pedagogical thinking.

## 6. Conclusion

Thus, the principles we have proposed make a fundamental contribution to increasing the effectiveness of modern multiaspect education. In contrast, classical methods rely on biological knowledge. In this paper, we have interpreted the specific contours of the essential nature and phenomenology of the integrative (additive) strategy and tactics for forming and developing specialized competencies.

The created and formulated new model of principles of the integrated approach includes four interconnected levels: cognitive value, content-disciplinary, digital-instrumental and project activity. This methodological package ensures the structural completeness and adaptability of the approach. In addition, it is adaptable and applicable to the tasks of natural science education in biological areas. Both the mastery of facts and the ability to integrate concepts, procedures and digital tools in real research and biotechnological tasks are needed.

We have articulated and interpreted a whole range of conceptual principles that can form the basis of a new modern educational worldview.

In particular, the cognitive multilayer principle (CMP) interprets the architecture of knowledge as a system of interacting layers. This approach can become the basis for constructing modern educational strategies that are authentic to the depth and type of disciplinary and interdisciplinary knowledge and data.

The principle of dynamic interdisciplinarity (DIF) interprets the process of disciplinary convergence as a nonlinear and emergent dynamic capable of generating new areas of biological educational knowledge.

The theoretical principle of cognitive–digital fusion (CDC) presents digitalization as an organic part of the cognitive process rather than an external tool.

The theoretical principle of problematic involvement (PIT) transforms the concept of problem-orientedness toward the meaningful experience of research reality.

The theoretical principle of engagement shift (EST) formulates involvement as a vector of semantic identification that becomes subjective co-authorship.

Taken together, the range of principles constitutes a new, conceptually and methodologically holistic framework within which the integrated approach can be understood not as a technique or method but as a way of thinking about education.

The integrated approach has high heuristic and transformative power. It is capable of ensuring the transition from informational learning to a subject-oriented model of education. The student is interpreted as an active carrier, interpreter and generator of knowledge and not only as an object of pedagogical influence.

The postulated principles open up prospects for further empirical and experimental developments. First, this is related to the operationalization of the proposed theories, the development of diagnostic and instrumental means for their implementation, and the adaptation of the integrated approach to various levels and profiles of higher education. The development of professional training for teachers capable of implementing these model principles in a hybrid, digital, and interdisciplinary educational environment is no less important.

Thus, the theoretical justification of the principles of an integrated approach proposed within the framework of this study forms a stable basis for the design of new educational practices and strategies that are adequate for the scientific, technological, and sociocultural conditions of our time.

## References

[1] S. Manapova, B. Shaikhova, S. Kumarbekuly, I. Mikushina, and I. Afanasenkova, "A set of online tools for teaching chemistry considering a systematic approach to the educational process," *International Journal of Innovative Research and Scientific Studies,* vol. 8, no. 1, pp. 1363-1379, 2025. https://doi.org/10.53894/ijirss.v8i1.4613

[2] K. Sanat, U. Nurbol, A. Bakhadurkhan, S. Anargul, D. Zukhra, and K. Gulfat, "Teachers' opinions about technological pedagogical content knowledge used in geography lessons," *World Journal on Educational Technology Current Issues,* vol. 14, no. 4, pp. 1217–1224, 2022. https://doi.org/10.18844/wjet.v14i4.7731

[3] B. Abdimanapov, S. Kumarbekuly, and I. Gaisin, "Technology for achieving learning objectives through a System-Activity approach and the development of critical thinking in geography studies," *Journal of Ecohumanism,* vol. 3, no. 8, pp. 11989–12003, 2024. https://doi.org/10.62754/joe.v3i8.5797

[4] K. Kaldybay, S. Kumarbekuly, A. Sharipkhanova, Z. Dautova, I. Afanasenkova, and M. Tarlaubay, "Identifying the factors that influence students' academic performance as a function of teaching qualities in Ahmed Yasawi International Kazakh-Turkish University," *Journal of Ecohumanism,* vol. 3, no. 6, pp. 859-868, 2024. https://doi.org/10.62754/joe.v3i6.4056

[5] R. K. Metalichenko, "Integrated learning technology as a means of forming the general cultural competence of students," *Social Policy and Social Partnership,* vol. 1, pp. 26–34, 2025. https://doi.org/10.33920/pol-01-2501-02

[6] B. Shaikhova, S. Kumarbekuly, Z. Igissinova, S. Manapova, and B. Tantybayeva, "Attainment and the development of the teaching competence of newly hired university teachers," *Journal of Ecohumanism,* vol. 3, no. 4, pp. 2387-2394, 2024. https://doi.org/10.62754/joe.v3i4.3762

[7] P. K. Ningtyas, H. R. Widarti, P. Parlan, S. Rahayu, and I. W. Dasna, "Enhancing students' abilities and skills through science learning integrated STEM: A systematic literature review," *International Journal of Education in Mathematics, Science and Technology,* vol. 12, no. 5, pp. 1161-1181, 2024. https://doi.org/10.46328/ijemst.4292

[8] F. Yanti, "Video-Based Learning as a Modern Distance Learning Method for Biology," *Journal of Digital Learning and Distance Education,* vol. 3, no. 5, pp. 108-1112, 2024. https://doi.org/10.56778/jdlde.v3i5.355

[9] Q. Ding, "Interdisciplinary Integration Theory and Practice Paths in Middle School Biology Education," *International Journal of Educational Teaching and Research,* vol. 1, no. 2, pp. 1-5, 2024. https://doi.org/10.70767/ijetr.v1i2.206

[10] O. V. Khotuliova, *Integrated Biology lessons in the modern education system*. Publishing House Sreda eBooks. https://doi.org/10.31483/r-112755, 2024, pp. 122–133.

[11] Z. Saidova, "The main peculiarities of the integrated approach and the role of teachers in implementation," *International Scientific Journal of Media and Communications in Central Asia,* 2024. https://doi.org/10.62499/ijmcc.vi6.60

[12] B. Fatmawati, M. Marzuki, F. Roshayanti, and P. K. Suprapto, "Fostering students' problem-solving skills through biology learning model integrated with Kurikulum Merdeka," *Jurnal Pendidikan Biologi Indonesia,* vol. 10, no. 2, pp. 392-403, 2024. https://doi.org/10.22219/jpbi.v10i2.32857

[13] E. F. Antiojo and J. B. Mendoza, "Examining the effectiveness of integrated learning strategies on science mastery level," *International Journal for Multidisciplinary Research,* vol. 6, no. 3, pp. 123–130, 2024. https://doi.org/10.36948/ijfmr.2024.v06i03.22072

[14] S. D. Siregar, Z. Zhafira, and R. Riandi, "Technology-based guided inquiry model learning innovation on environmental change material," *BIODIK,* vol. 10, no. 2, pp. 101-110, 2024. https://doi.org/10.22437/biodik.v10i2.32890

[15] C. Bhoi, "Evaluating the effectiveness of innovative learning approaches in teaching biology to secondary school students: A comparative study of traditional and interactive pedagogical methods," *Journal of Education Method and Learning Strategy,* vol. 2, no. 03, pp. 894–906, 2024. https://doi.org/10.59653/jemls.v2i03.779

[16] S. U. Laiskhanov, "A study of the effects of soil salinity on the growth and development of maize (Zea Mays L.) by using Sentinel-2 Imagery," *OnLine Journal of Biological Sciences,* vol. 22, no. 3, pp. 323–332, 2022. https://doi.org/10.3844/ojbsci.2022.323.332