"ION CREANGĂ" STATE PEDAGOGICAL UNIVERSITY

OF CHISINAU

With manuscript title

CZU:37.025:57+004(043.2)

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USE OF ICT TOOLS IN THE BIOLOGY SUBJECT IN THE CONTEXT OF DEVELOPING HIGH SCHOOL STUDENTS' MOTIVATION FOR LEARNING

Speciality 532.02. School Didactics on Education Levels and Subjects (Biology)

Chișinău, 2025

The thesis was developed within the Doctoral School "Education Sciences", "Ion Creangă" State Pedagogical University of Chisinau

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The public defense of the thesis will take place on 16.04.2025, at 14:00, in the Senate Hall of the "Ion Creangă" State Pedagogical University, bl. 2, str. Ion Creangă 1, MD 2069.

The summary of the doctoral thesis can be consulted on the website of Ion Creangă State Pedagogical University (www.upsc.md) and on the website of the National Agency for Quality Assurance in Education and Research (www.cnaa.md) The summary was sent on 13.03.2025

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CONCEPTUAL BENCHMARKS OF THE RESEARCH

The Biology subject, in relation to ICT tools, creates advantageous perspectives for an interactive learning process, in the context of the degree of complexity and diversity of thematic contents. The difficulty in motivating high school students is a dominant factor, because selective motivation influences school success and learning outcomes.

The topicality and importance of the research topic is welcome in the future specialists' training in the double study programmes: Biology and Chemistry, Chemistry and Biology, Geography and Biology, of the "Ion Creangă" State Pedagogical University of Chisinau.

Internationally, this topic is analyzed separately, from the perspective of several aspects. UNESCO proposes the *Information and communication technology in education: a curriculum for schools and programme of teacher development, which supports the strategies for implementing ICT tools [19].*

The European Commission publishes the work of the author Christine Redecker *European Framework for the Digital Competence of Educators DigCompEdu* (European Framework for the Digital Competence of Educators: DigCompEdu), which proposes ways to develop and valorize teachers' digital competence [7]. At the same time, in 2022, a new version of the European Strategy for Digital Competences (DIGCOMP), authors Vuorikari Riina, Kluzer Stefano, Punie Yves, is approved, which proposes a reference framework for digital competences (DigComp 22) [35]. The Recommendation of the Council of the European Union provides a series of strategies or strategic approaches to the application of ICT tools in education through developed digital competences [6].

In the Development Strategy "Education 2030", the Government of the Republic of Moldova proposes solutions for the development of education in the context of global digitalization [31]. In In the Digital Competence Framework for Teachers in Education, the

Ministry of Education and Research of the Republic of Moldova includes teachers' digital competence profiles [3].

Learning with ICT has been studied by a number of researchers, including: Marc Prensky, Digital Natives, Digital Immigrants [27], Yasmin B. Kafai, Mitchel Resnick [18], Karen Cator [4], Michael Fullan [13], etc.

Among the researchers from the Republic of Moldova: Anatol Gremalschi [15], Valeriu Cabac [2], Andrei Braicov and Sergiu Corlat [9], L. Chiriac, A. Globa [5], etc., have made significant contributions regarding the application of ICT tools in the educational system.

Selectively, research on the integration of ICT tools in the Biology teaching process is described by Yassanne Garraway-Lashley [14], Gertrude Kanayo Ezekoka [12], Ricardo Trumper [32].

Motivation for learning is studied by a number of researchers such as Rolland Viau [33], Victor H. Vroom [34], Abraham Maslow [20], David MacClelland [122] and John William Atkinson [1], Johnson D. W. and the team of authors [17], Estela Straicov [30].

The application of ICT tools in the Biology educational process is analyzed in the good practices of the authors Iurie Cristea [10], Diana Coșcodan and Lora Moșanu-Șupac [8] etc.

The author determines the following **contradictions:** 1. The pace of the development of information and communication technologies is much faster compared to the development of methodological benchmarks for their integration into the teaching process, including in the discipline of Biology; 2. The level of high school students' motivation for learning vis-à-vis the formation of specific competencies in the Biology subject; 3. The complexity of the requirements for applying ICT in the educational process in relation to teachers' professional competences and skills.

In the context of the indicated contradictions, **the research problem** was formulated: establishing scientific and methodological benchmarks for the application of information and communication technologies in the teaching process with a positive impact on the

values of high school students' motivation for learning and focused on streamlining the process of studying the Biology subject.

The purpose of the work: to develop the theoretical and methodological basis for the implementation and use of ICT tools in the Biology subject in order to increase high school students' motivation for learning.

Research objectives: 1. Analysis of theoretical benchmarks regarding high school students' motivation for learning facilitated by ICT tools; 2. Development of the Model for Using ICT Tools in the Biology Subject in the Context of Developing High School Students' Motivation for Learning; 3. Argumentation of the Methodology for implementing the Pedagogical Model developed within the teaching process in the school Biology subject ; 4. Experimental validation of the Model for Using ICT Tools in the Biology Subject in the Context of Developing High School Students' Motivation for Learning; 5. Broadening the spectrum of instructional-methodical resources in the field of Natural Sciences (in particular, the school discipline of Biology) focused on the implementation of ICT in the teaching process.

General hypothesis

The methodology for using ICT tools will stimulate high school students' motivation for learning in the Biology subject: 1. The conceptual benchmarks will be established, the general and specific psychopedagogical conditions for learning in the Biology subject will be respected; 2. The hardware and software tools researched will be systematically applied in the teaching process in the Biology subject; 3. The continuing education courses for teachers will be in line with the methodologies related to the use of ICT tools in the Biology subject; 4. The interdependence between the use of the Methodology for integrating ICT tools in the Biology teaching process and the values of high school students' motivation for learning will be elucidated. 5. The Pedagogical Model for Using ICT Tools in the Biology Subject in the Context of Developing High School Students' Motivation for Learning will be created, which will contribute to satisfying students' knowledge

needs in the Biology subject.

Following the synthesis of the research methodology, necessary to obtain the research results, the following methods were selected: *theoretical, empirical, descriptive*.

The scientific novelty consists in justifying the connection between ICT tools used in the educational process in Biology and their impact on high school students' motivation for learning in the Republic of Moldova. **The originality of the research** is based on the fact that there was developed the Model for Using ICT Tools in the Biology Subject in the Context of Developing High School Students' Motivation for Learning and the individualization of the actions for implementing the authentic Pedagogical Model of the present research.

The important scientific problem solved in the research lies in establishing scientific and methodological benchmarks for applying information and communication technologies in the Biology teaching process with beneficial results on high school students' motivation for learning, which led to the development of the Model for Using ICT Tools in the Biology Subject in the Context of Developing High School Students' Motivation for Learning and its implementation Methodology, which contributed to resolving the coherence between the use of ICT tools in the Biology subject and increasing high school students' motivation for learning, as well as the efficiency of the teaching process in this school discipline.

The publications on the topic of the doctoral thesis (40 publications) present a truthful argument on the research direction.

THESIS CONTENT

In Chapter 1, ***Theoretical Benchmarks Regarding High School Students' Motivation for Learning Facilitated by ICT Tools***, there are elucidated the theories of researchers on the motivation for learning, according to the age characteristics of high school students, with reference to the needs of motivation for learning and the psycho-

pedagogical conditions that outline the profile of the high school student motivated to learn.

Based on the theoretical framework, certain values of motivation were analyzed, such as students' behavior, self-affirmation, needs, curiosity, benefits, preferences, perseverance, and willpower. These dimensions were measured and correlated with the use of ICT tools [11] in the learning process of high school students.

At the same time, a qualitative study was conducted on the development of information and communication technologies for education (ICTE), including the main national and international regulations that laid the foundation for the digitalization of education in the Republic of Moldova, the way they were integrated, and their impact on the teaching process in the subject of Biology. Thus, taking into account the general development of ICT, five main stages were highlighted, their characteristics, and respectively, the ICT tools available for each stage: 1) before 1985 (Pre-digitalization period); 2) 1985 - 2000 (Initiation period); 3) 2000 - 2010 (Awareness period); 4) 2010 - 2019 (Transition and expansion of digitalization period); 5) 2019 - present (1. COVID-19 period and acceleration of digitalization; 2. Post-pandemic period and the future of education digitalization).Thus, ICT tools, later applied in the pedagogical experiment, included electronic presentations, digital sensors, electronic magazine and artificial intelligence.

The theoretical investigation on Information and Communication Technologies has drawn some conclusions according to which if the implementation strategies of digital tools take place in the context of an interactive, personalized and responsible teaching process, they can bring benefits in the development of the high school students' personality.

The described synthesis is presented in 6 subchapters that detail the theoretical benchmarks of the research topic.

Chapter 2, ***Pedagogical Model for Using ICT Tools in the Context of Developing High School Students' Motivation for***

Learning includes a part of the research that refers to the formative valences of ICT tools in the Biology teaching-learning-evaluation process.

The analysis of Biology Curriculum (grades X-XII) from the perspective of using ICT tools in the teaching-learning-evaluation process illustrates the percentage differences by grades and high school learning profiles of recommended activities and learning products through the application of ICT tools, Fig. 2.1. Thus, the largest percentage share is in grade XII, real profile – 17.39% out of 100%, constituting the smallest difference between the total number of recommended activities and learning products 82.61%. Then, grade X, real profile and grade XII, humanistic profile follow with an equal ratio in both grades – 11.76%. In grade X, humanistic profile, recommended activities and learning products with the integration of ICT tools represent 6.66%.

In grade XI, humanistic profile, ICT tools are recommended in 6.25% of activities and learning products. The lowest index is in the 11th grade, real profile – 5%.

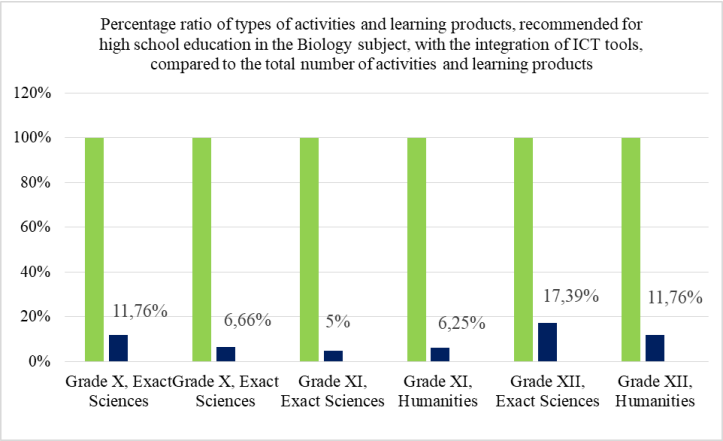


Fig. 2.1. Percentage ratio of activities types and learning products, recommended for high school education in the Biology subject, with the integration of ICT tools, compared to the total number of activities and learning products

The percentage analysis of the use of ICT tools in teaching Biology highlights significant differences between classes and profiles, emphasizing the need for a structured approach to their efficient integration into the teaching process. In this context, there was developed a *Pedagogical Model for using ICT tools in the Biology subject in the context of developing motivation of high school students*, as shown in Fig. 2.2.

The conceptual benchmarks present one of the main components of the Pedagogical Model in Fig. 2.8, which refers to the Reference Framework of the National Curriculum of the Republic of Moldova "... where the foundations, methodology and praxiology of curricular policies for general education are specified" [16].

The Biology Curriculum for grades X – XII includes a system of contents oriented towards the formation of the necessary competences for high school students, promoting the interdisciplinary and transdisciplinary learning nature. The contents proposed in the curriculum maintain the motivational rhythm of high school students' learning through the application of various teaching resources, including ICT tools.

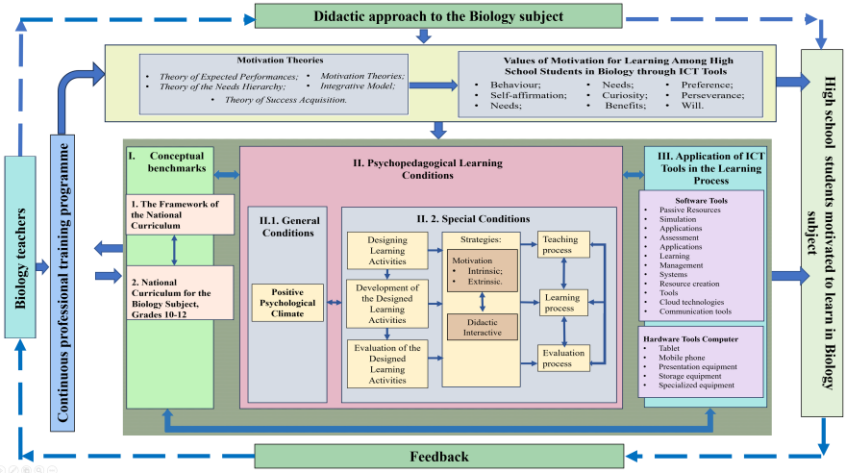


Fig. 2.2. The Pedagogical Model for Using ICT Tools in the Biology Subject in the Context of Developing High School Students' Motivation for Learning

Therefore, high school students' learning outcomes can be achieved through interactive learning activities, while respecting the psychopedagogical conditions favorable to intrinsic and extrinsic motivation.

The efficiency of integrating ICT tools depends *on the design of learning activities, the development of the designed activities and the evaluation of the designed learning activities,* in relation to the teacher's teaching style, the student's learning style and the number of students in the classroom.

Teaching strategies present a component part of the specific psychopedagogical conditions for the efficient use of ICT tools.

Software and hardware tools are constantly changing in relation to the evolution of ICT tools in the digital age. Worldwide, companies specializing in the creation of new software and hardware products also involve the educational system. Thus, there is a need to complement the existing ICT teaching resources in learning spaces with new generations of software and hardware tools. The author mentions this thought, because the evolution of software and hardware tools will determine the process of applying and adapting ICT tools, derived from *the Pedagogical Model for Using ICT Tools in the Biology Subject in the Context of Developing High School Students' Motivation for Learning.*

The ICT tools, used in the educational process in the Biology discipline, are analyzed from the perspective of developing the values of high school students' motivation for learning, determined from the following theories of motivation: *Expected Performance Theory*, *Need Hierarchy Theory, Integrative Model, Success Acquisition Theory.* As a result, the ICT tools model the following values of high school students' motivation for learning in the Biology subject: conduct, self-affirmation, needs, necessities, curiosity, benefits, preference, perseverance, will.

The developed Pedagogical Model differs from other pedagogical models focused on integrating ICT into the teaching

process by: identifying the set of high school students' motivation values to learn Biology with ICT tools (conduct, self-affirmation, needs, requirements, curiosity, benefits, preference, perseverance, will); selecting the most effective digital tools that contribute to increasing learning motivation (for example, online journals, digital sensors, artificial intelligence, etc.); focusing digital resources on increasing the values of learning motivation in the school Biology subject through the perspective of psychopedagogical learning conditions; integrating the Life Long Learning concept for the teachers' continuous training; interactive teaching methods from the perspective of integrating STEM education; the proposed Model facilitates the orientation of the entire teaching process towards improving students' learning experiences, transforming them into active actors of the teaching process.

The essential properties of the developed Pedagogical Model are: versatility, flexibility in application, continuity of the Model, multifunctionality and originality.

The Methodology for implementing the created Pedagogical Model depends on the digital skills of the teaching staff and students. The teaching staff has a high degree of responsibility for planning, organizing, conducting the evaluation of the teaching approach and the results obtained from the application of ICT teaching resources.

In the Biology subject, the author created **the electronic ProBiologic Rythm journal,** which can be accessed at the link https://sites.google.com/view/ritmprobiologic .

The *ProBiologic Rythm* journal presents a website with pages with a heterogeneous background. The online ProBiologic Rythm journal promotes the attractive and motivational nature of Biology science. The group of coordinating students collaborates and develops various learning products that are placed on the thematic pages of the journal [28].

Fig. 2.3. Pop-up menu containing links to thematic pages of the online *ProBiologic Rythm* *journal*

The report in Fig. 2.4, made with the Google Analytics service, shows that globally, the online ProBiologic Rythm journal has accesses from different continents: North America, South America, Europe, Asia, Australia, Africa. This index presents a means to encourage and motivate students to continue the journal's activity in the online environment, and therefore, motivates them for continuous Biology learning.

Thus, the countries with the most accesses and the total number of sessions are: in first place – the Republic of Moldova with 15,358 sessions, in decreasing order it is followed by: Romania (2058 sessions), United States of America (132 sessions), Germany (67 sessions), Italy (57 sessions), United Kingdom (41 sessions), France (32 sessions), Ukraine (30 sessions), Russia (23 sessions), Spain (19 sessions), Israel (14 sessions), Ireland (10 sessions), Netherlands (7 sessions), Turkey (7 sessions), Belgium (6 sessions).

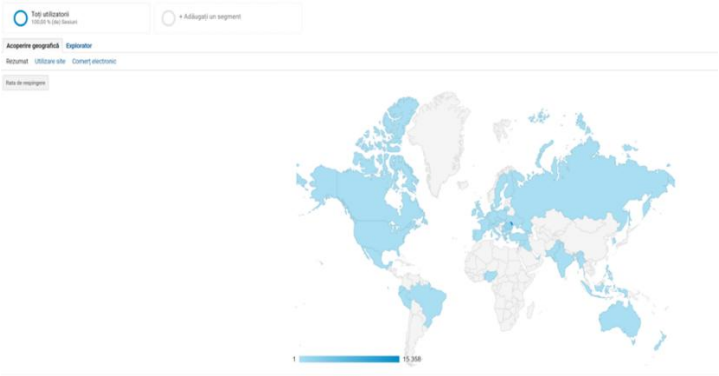
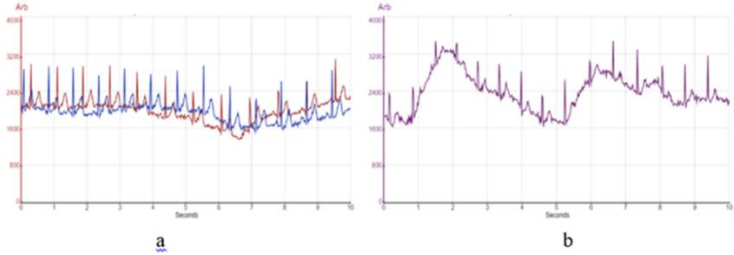


Fig. 2.4. Map of countries from which the online *ProBiologic Rythm* journal was accessed

The online *Rythm ProBiologic* journal features some learning products created by high school students through the application of ICT resources, which are recommended by the Biology curriculum, 2019 edition. As a result, out of 8 (100%) types of learning products recommended by the curriculum with reference to the application of ICT tools for the real profile, grades X– XII, 5 (62.5%) are found on the pages of the online journal, and for the humanities profile, out of 5 (100%) - 3 (60%) are in the online Rythm ProBiologic journal.

Digital labs, electronic presentations, AI, present motivating ICT resources for high school students in studying Biology.

Depending on the purpose of the research, for recording data and formulating the necessary conclusions, ICT tools can contribute to the exploration of reality, data collection, data recording and dissemination of results [22]. For example, an experiment can be carried out on the topic *The human blood system*. *The heart*, grade XI, with the *NeuLog* application and the *NUL-218* electrocardiogram recording sensor, where the heart electrical impulses can be measured through the electrocardiogram. The materials of the digital experiment are modules and sensors: *NeuLog* software; *USB-200* module; *NUL-218* electrocardiogram recording sensor [26].



a b

Fig. 2.5. Comparative analysis of the experiment graphs performed with the *NeuLog* software: a – electrocardiogram of a man in a calm and stressed emotional state; b – electrocardiogram of a man recorded after 20 squats

Thus, we tend to believe that the digital laboratory (NeuLog) motivates students to learn by using the vast set of opportunities and tools it makes available. The students' learning outcomes will be subordinated to the specific competencies of the Biology subject[25].

Digital Biology laboratories, equipped with ICT tools, can support students' interest in the Biology subject, if the teacher identifies solutions to combine several teaching methods specific to the Biology subject.

Electronic presentations in Biology are effective tools for communicating complex information and making scientific subjects more accessible and interesting for students. In the digital age, the use of electronic presentations in Biology education is becoming increasingly relevant and engaging. This teaching method not only transforms the learning experience, but also stimulates high school students' motivation to explore and understand the specific features of Biology [7].

In the context of the Biology learning process, the diversity of electronic presentations included PowerPoint [1], Prezi, and Powtoon.

Fig. 2.6. Sequence from the Powtoon presentation on the topic *Hygiene*, dysfunctions and diseases of the nervous system, grade XI

As a result, e-presentations can play a significant role in motivating high school students in Biology. The use of ICT tools can bring many advantages to the learning process and stimulate students' interest and engagement.

Artificial intelligence (AI) is increasingly actively penetrating everyday life, creating clear premises for its application in the educational process. The author of this research adopted AI technologies for formulating learning tasks in Biology.

In the content unit *Basics of Genetics*, the topic *Mendelian Laws of Transmission of Hereditary Characters (Monohybrid and Dihybrid Crossing)*, grade XII, real profile and in the humanistic profile, *G. Mendel's Laws of Transmission of Hereditary Characters (Monohybrid Crossing)*, there is proposed the learning activity on solving genetics problems. The attractiveness of this learning task increases students' motivation to get involved in identifying creative and original answers, through the interactivity offered by artificial intelligence.

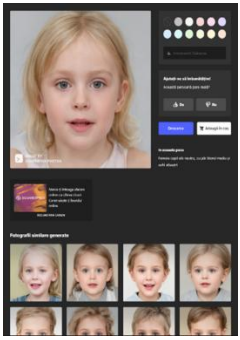


Fig. 2.7. Setting characters by genotypes of the Genetics problem in the Generated photos application

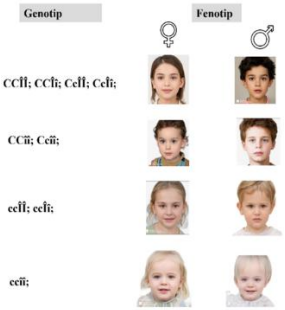


Fig. 2.8. Phenotypic representation of the offspring investigated in the Genetics problem with Generated photos

One of the elements of **integrating the STEM concept into the Biology teaching process** was the development of the *Guide for the implementation of STEM technology and the use of sensors in the field of Natural Sciences*, from the perspective of Biology, in the context of developing high school students' motivation for learning in

the Biology subject, being one of the results of the research conducted by the author.

In this context, the STEM projects, included in the guide, represent an innovative way to motivate high school students to approach the field of Biology and to understand its importance in the contemporary world through *the connection with reality, interdisciplinarity, development of practical skills, inspiration for a career.*

Table 2.1 indicates some experiments in Biology, which can be carried out by students using *NeuLog* sensors.

Table 2.1. Experiments recommended for students using *NeuLog* sensors in the content units of the Biology Curriculum, grades X-XII, 2019 edition

Grade	Curriculum Content Unit	Recommended experiments
X	The cell, the morphofunctional unit of organisms	***Diffusion through the cell membrane*** (B-2, ver. 3.2.11) Conductivity recording sensor (NUL-215)
XI XII	Humans' breathing	***Breathing*** (B-3, ver. 3.2.8) Oxygen Recording Sensor (NUL-205)
	Circulation of substances in the human body	***Heart Rate and Physical Activity*** (B-19, ver. 3.2.12) Heart Rate and Pulse Sensor (NUL-208)

Thus, the correct use of ICT tools in the Biology teaching-learning-assessment process can have a significant impact on students' motivation. Therefore, ICT-based literacy in the context of Biology is not limited to accessing online information, but also involves the development of specific skills such as digital reading, digital writing and digital mathematical calculation. These digital skills can play a significant role in motivating learning in the Biology subject.

Chapter 3. ***Experimental Validation of the Pedagogical Model and the Developed Methodology*** describes the pedagogical experiment that took place in two consecutive stages: (1) the ascertaining stage, during which surveys were conducted with students and teachers to measure the values of learning motivation in the context of selecting and using IT resources; there were identified the control and experimental samples with the verification of the statistical hypotheses H_0 and H_1, which confirmed their homogeneity; (2) the training stage during which the Pedagogical Model *for Using ICT Tools in the Biology Subject in the Context of Developing High School Students' Motivation for Learning* and the developed Methodology were implemented.

The general objective of the pedagogical experiment established by the author is to validate the Pedagogical Model *for Using ICT Tools in the Biology Subject in the Context of Developing High School Students' Motivation for Learning* through statistical analysis of the data obtained.

The research hypothesis put forward within the pedagogical experiment: if the pedagogical conditions specified by the Pedagogical Model are respected and the developed Methodology is applied, then the level of high school students' motivation for learning in the Biology subject will be significantly improved.

The following **variables** were used in the experiment:

- independent: control and experimental samples, developed teaching strategies, studied curricular contents, applied digital resources (hard, soft), technical conditions of the study space;

- dependent: the level of high school students' motivation values for learning Biology with the help of ICT tools, the degree of using ICT tools in the Biology teaching process by teachers.

The pedagogical experiment took place during the years of study: 2021-2022; 2022-2023. The subjects of the experiment were 167 high school students, Table 3.1, from the Public Institution "Alecu Russo" Theoretical High School in Cojușna, (84 students in the

experimental group; 83 students in the control group) and 294 teachers in the discipline Biology in the Republic of Moldova, Table 3.2.

Table 3.1. Numerical composition of the subjects (students) of the pedagogical experiment

No.	Year of study	Number of students		
		Experimental sample	Control sample	Total
1.	2021-2022	31	55	**86**
2.	2022-2023	53	28	**81**
Total		**84**	**83**	**167**

Table 3.2. Numerical composition of the teachers participating in the pedagogical experiment

Continuing professional development session, UST		Continuing professional training session within AOIEP	
Year of study	No. of teachers participating in the experiment	Year of study	No. of teachers participating in the experiment
2020-2021	181	2022 – 2023	113
Total: 294 teachers participating in the experiment			

The ascertaining stage of the pedagogical experiment

The following objectives were established for the assessment stage: 1. Measuring the level of the integration of ICT resources into the Biology teaching-learning-evaluation process focused on increasing high school students' motivation for learning (teachers). 2. Identifying digital tools with a positive impact on high school students' motivation for learning Biology. 3. Measuring high school students' motivation values for learning in the Biology subject determined by the application of ICT tools (conduct, self-affirmation, needs, requirements, curiosity, benefits, preference, perseverance, will). 4. Identifying the control and experimental samples with verification of their homogeneity.

This stage of the pedagogical experiment aimed at identifying students' opinions regarding the degree of motivation for learning in the Biology subject in relation to the application of ICT tools through the behavioral, personal, sociocultural, cognitive dimensions of the self, but also at determining the level of using ICT tools in the Biology teaching process by teachers in terms of increasing students' motivation for learning.

To achieve objectives 1 and 2 of the ascertaining stage, initially, three questionnaires were created. Following the analysis of the specialized literature, the first was developed and applied to the teachers, which proposed various situations of applying ICT tools in the Biology teaching process and their action on students' desire to learn, carried out at the continuing professional training courses of Biology teachers, within the Continuing Professional Training Center of Tiraspol State University.

The questionnaire was completed by 181 (100%) teachers aged 22-75 years, of which 164 (90.6%) were female and 17 (9.4%) were male, who work in high school and middle school education.

In order to achieve the third objective of the ascertaining stage of the pedagogical experiment, two surveys were developed and applied for high school students, included in the research samples, which aimed at identifying the initial situation regarding the level of motivation values for learning in the Biology subject. As a result, there were researched the following motivational values of the Biology teaching-learning-evaluation process: *conduct; self-affirmation; needs; necessities; curiosity; benefits; preferences; perseverance; will.*

With the help of survey I, there were researched the values: *conduct, self-affirmation, needs and necessities*, and with survey II – *curiosity, benefits, preference, perseverance and will*.

In order to analyze the data obtained during the ascertaining stage, there were formulated the null hypothesis H_0 and the alternative hypothesis H_1 (research).

In order to approve or reject the null hypothesis H_0 and consequently to reject or approve the research hypothesis H_1, there was performed a statistical analysis of the data obtained from the application of the two questionnaires to high school students from the experimental and control samples. Since the research variables that refer to the level of high school students' motivation values for learning Biology with the help of ICT tools are nominal, categorical, and the independent variable, sample, is also nominal, with two categories

(control and experimental), the observations are independent and no student chose more than one value for each dependent variable investigated, then the χ^2 statistical test of association or independence can be applied.

The results of the χ^2 test attest that **there are no significant** differences between the values of the high school students' learning motivation variables in the Biology subject, influenced by the use of ICT tools, when comparing the control sample with the experimental one ($p>0.05$), for all types of motivation values analyzed in this research, the academic years 2021-2022 and in the year 2022-2023. This fact allows the confirmation of the null hypothesis put forward that there are no significant differences between the samples included in the experiment, therefore they are at the same level and therefore the start of the formation stage of the pedagogical experiment takes place under the same conditions for both samples.

In conclusion, the results of the survey, obtained at the initiation stage of the pedagogical experiment, in the year 2021-2022, highlight the problems regarding high school students' motivation to learn with the help of ICT tools. The same results were obtained at the initiation stage of the pedagogical experiment in the year 2022-2023 (81 students), with a deviation of ±5%. Thus, the third and fourth objectives of the observational experiment were achieved.

For the **formation stage**, the author formulated the following objectives: 1. Identifying the differences between the initial and post-training values of the degree of using ICT tools in the Biology teaching process by teachers from the perspective of high school students' motivation for learning; 2. Identifying the differences between the post-experimental values of high school students' motivation for learning, as a result of the use of ICT tools, of the samples involved in the experiment; 3. Validating the Pedagogical Model *for Using ICT Tools in the Biology Subject in the Context of Developing High School Students' Motivation for Learning*, by interpreting the results of the statistical tests performed.

As a result, the experimental programme is complemented with the objective of developing teachers' digital competences and using ICT tools in the Biology teaching process.

The continuous professional training course *Ensuring inter- and transdisciplinary aspects in the Biology teaching process through the integration of ICT resources*, organized for Biology teachers (113 subjects) within the Public Association "*Innovation in Performance Education",* aimed at identifying the possibilities of integrating ICT resources in the Biology teaching process so that students become more motivated towards this discipline.

The results obtained from the survey confirm those obtained during the continuous professional training of Biology teachers at TSU (181 subjects), with a deviation of ±5%. At the end of the training program, teachers completed a final questionnaire to obtain data on the integration of ICT in the Biology training process in the context of motivating students for learning. Thus, in order to achieve the first objective of the training phase, the values of the data obtained before the training were compared with those after the continuous training of the biology teachers, in order to test the efficiency of the training course. To this end, the hypotheses corresponding to the research stage were put forward.

In order to verify these assumptions, the Wilcoxon test (W) was applied to the paired samples, the results of which are presented in Table 3.3.

To test these hypotheses, the Wilcoxon (W) test for paired samples was applied, the results of which are significant ($p < 0.05$), then it results that there are significant differences between the results of teachers' survey participating in the training session, for all items, regarding the use of ICT tools in the Biology discipline, from the perspective of motivation for learning (pretest-posttest). Thus, the veracity of the research hypothesis H_1 is attested, because the significant differences between the results of the pre- and posttest survey of Biology teachers were confirmed, obtaining significantly

more qualitative results at the end of the continuous professional training course. In this context, the first objective of the training stage within the pedagogical experiment carried out is considered achieved and the efficiency of the continuous training course is confirmed.

Table 3.3. Results of the Wilcoxon W test comparing the results of the teacher questionnaire on the use of ICT tools in the discipline of Biology, from the perspective of motivation for learning (pretest-posttest)

No. do	Items	mediate pretest	mediate post-test	W	p
1.	Do you appreciate the intensity of your use of ICT resources to maintain students' interest in the educational approach to the Biology discipline?	1.65	1.11	1893	< .001
2.	Do you appreciate the frequency of using ICT in various learning motivation activities and the creation of learning products in Biology?	1.82	1.27	2198	< .001
3.	Use of biological scientific language regarding structures, processes, phenomena, laws, concepts in various communication contexts	1.8	1.4	1794	< .001
4.	Investigating the living world using specific methods and means to improve the quality of life and the environment	1.85	1.54	1068	< .001
5.	Involvement in activities to maintain one's own health and that of those around them by applying interactive methods to form healthy behavior	1.83	1.48	1482	< .001
6.	Participation in biodiversity protection actions through partnership in order to solve ecological problems at the individual, local and global levels	1.94	1.61	1704	< .001
7.	Completing classroom assignments	2.16	1.73	1617	< .001
8.	Doing homework	1.97	1.75	1373	0.016
9.	Extracurricular educational activities	1.83	1.65	1511	0.049

In order to achieve the second objective of the training stage of the pedagogical experiment, a survey of the students involved in the experiment was conducted upon its completion, and the results obtained by the two samples (experimental and control) were compared with each other.

The results of the χ^2 test, measured at the end of the experimental training phase in the 2021-2022 academic year (86 students) and for the 2022-2023 academic year (81 students), when comparing the control sample with the experimental one ($p<0.05$), for all types of motivation values analyzed in this research. Therefore, it is

found that the significant differences are in favor of the experimental sample, in the sense that for it a significantly higher percentage of qualitative responses of the type "very much", "a lot", "very often", "often", "very well" and "well" was recorded. This fact allows the confirmation of the H_1 research hypothesis put forward that between the samples included in the experiment **there are significant differences** in relation to the post-experimental values of high school students' motivation for learning, as a result of the use of ICT tools in the Biology subject, in the sense that significantly more qualitative results were obtained in the experimental sample than in the control one.

The Cramer's V effect size coefficient, calculated for the χ^2 test of association or independence, measures the effect of the independent variable (the developed teaching strategies) on the dependent variable (the level of high school students' motivation values for learning Biology with the help of ICT tools) and was found to be from medium to strong or strong, with minor exceptions, which demonstrates the efficiency of the Model and the developed Methodology.

The confirmation of the results obtained for the experimental year 2021-2022 and for the academic year 2022-2023, higher for the experimental samples from each year of the experiment, allows the validation and verification of the efficiency of the Pedagogical Model *for Using ICT Tools in the Biology Subject in the Context of Developing High School Students' Motivation for Learning* and the developed Methodology.

CONCLUSIONS AND RECOMMENDATIONS

The educational environment is open to new directions of teaching methodology, thus creating favorable contexts for research and innovation. As a result, the theoretical and praxiological basis of the thematic area of investigation was developed and the following **conclusions** were formulated:

1. Analyzing scientific research on the theory of motivation, educational policies, national and international normative documents, studied through the lens of the learning process of high school students, with an emphasis on the inclusion of ICT in the teaching process, it can be stated that: (1) high school students' motivation for learning depends on the combination of psycho-pedagogical modalities and conditions; (2) rapid digital development considerably outpaces the progress in developing new methodologies for integrating ICT into the Biology teaching process with a focus on increasing motivation for learning, which are of a general and fragmented nature; (3) the increased demand for integrating ICT into the educational process often exceeds teachers' professional skills and abilities; (4) difficulties in motivating high school students to learn remain a major obstacle, but the correct management of the appropriate integration of ICT into the Biology teaching can significantly contribute to the development of students' personalities; (5) there is a need to strengthen the didactic dimensions that support the increase in motivation for learning at all educational levels, by effectively using digital resources; (6) measurable values of high school students' motivation for learning Biology have been identified: *conduct, self-affirmation, needs, necessities, curiosity, benefits, preferences, perseverance, will.*

2. The *Pedagogical Model for Using ICT Tools in the Biology Subject in the Context of Developing High School Students' Motivation for Learning* was developed, which represents a significant teaching support for improving the motivation values of high school students in Biology. The essential properties of the developed Pedagogical Model are: versatility, flexibility in application, continuity of the Model, multifunctionality and originality.

3. The Methodology for Implementing the Pedagogical Model *for Using ICT Tools in the Biology Subject in the Context of Developing High School Students' Motivation for Learning* was developed and scientifically argued. The methodology created includes: (1) theories and concepts focused on increasing motivation for learning *(Expected Performance Theory, Needs Hierarchy Theory, Integrative Model, Success Acquisition Theory, STEM/STEAM concept, Life Long Learning Concept for teachers' continuous training);* (2) psychopedagogical learning conditions necessary

for increasing intrinsic and extrinsic motivation; (3) interactive strategies and methods; (4) digital teaching tools (electronic journals, digital laboratories, digital sensors, artificial intelligence, electronic presentations, etc.) being oriented towards the training and development of specific skills in the Biology subject and students/teachers' digital skills, facilitating the implementation of inter- and transdisciplinary activities with actions to motivate high school students for learning and research activities.

4. The validation of the effectiveness of the Pedagogical Model *for Using ICT Tools in the Biology Subject in the Context of Developing High School Students' Motivation for Learning* and the developed Methodology was achieved by conducting the pedagogical experiment over two years (2021-2022, 2022-2023) on a sample of 167 high school students. The statistical analysis of the results of the pedagogical experiment conducted using Wilcoxon and χ^2 tests for independent samples demonstrated significant differences between the experimental and control samples in relation to the post-experimental values of high school students' motivation for learning, as a result of using ICT tools in the Biology discipline. The Cramer's V effect size coefficient, calculated for the χ^2 test of association or independence, was found to be *medium to strong or strong*, which demonstrates the efficiency of the Pedagogical Model and the Methodology developed on high school students' motivation values in the Biology discipline facilitated by the integration of information and communication technologies into the teaching process.

5. The validation of the Pedagogical Model involves the conscious choice of hardware and software resources in accordance with students' age characteristics. Monitoring the application of digital resources and constant management of the impact of these tools on learning motivation depends on teachers' professional skills, teachers who are capable of ensuring the efficiency of the Methodology of the developed Pedagogical Model.

6. The spectrum of teaching resources in the Biology subject regarding the efficient integration of information and computational technologies in the teaching approach was expanded by publishing the guide [29] and creating the online ProBiologic Rythm journal [23, 24, 25].

7. The completion of all stages of the research led to the achievement of the purpose, objectives and the full resolution of the research problem, which consists in establishing scientific and methodological benchmarks for the application of information and communication technologies in the teaching process with beneficial results on the values of high school students' motivation for learning by applying the Model for *Using Information and Communication Technology (ICT) Tools in Biology in the Context of Developing High School Students' Motivation for Learning* and its implementation Methodology.

The results obtained in the process of solving the research problem, achieving the purpose and objectives of the research were published in a number of scientific and didactic works.

Based on the conclusions formulated, the following **recommendations** are made:

1. It is recommended to continuing education centers, specialized departments to develop methodological supports for the implementation of ICT tools in the Biology subject based on the Pedagogical Model for Using Information and Communication Technology (ICT) Tools in Biology in the Context of Developing High School Students' Motivation for Learning.

2. Application of the Pedagogical Model for *Using Information and Communication Technology (ICT) Tools in Biology in the Context of Developing High School Students' Motivation for Learning* and of the Methodology created in the development of new teaching materials in Biology (including digital), in the writing of new textbooks in the Biology school discipline, including within the conceptualization of the new Biology curriculum.

3. Expanding the theoretical and praxiological foundations of the Pedagogical Model *for Using Information and Communication Technology (ICT) Tools in Biology in the Context of Developing High School Students' Motivation for Learning* in related research fields (bioinformatics, biophysics, biochemistry, etc.).

4. Dissemination of research results within the initial training of students and master's students in the Biology Didactics discipline and within the pedagogical internships.

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ADNOTARE

Placinta Daniela

Valorificarea instrumentelor TIC la disciplina Biologie în contextul dezvoltării motivației pentru învățare a liceenilor

Teză de doctor în științe ale educației. Chișinău, 2025

Structura tezei: Teza cuprinde introducerea, urmată de 3 capitole în care se regăsesc: 49 de figuri și 19 tabele, incluziv, concluzii și recomandări, 117 de pagini de text de bază, bibliografie reprezentată de 219 de surse, 6 anexe. În baza cercetărilor la tema tezei au fost publicate 40 de lucrări.

Cuvinte-cheie: valorificarea instrumentelor TIC, motivație pentru învățare, învățământ liceal, didactica biologiei, model pedagogic, metodologie, experiment pedagogic, validarea modelului pedagogic.

Scopul lucrării: elaborarea bazei teoretice și metodologice de implementare a Modelului axat pe valorificarea instrumentelor TIC la disciplina Biologie, pentru a spori motivația învățării elevilor liceeni.

Obiectivele cercetării: determinarea caracteristicilor psihologice ale liceenilor pentru învățare; identificarea resurselor TIC și aplicabilitatea lor în procesul didactic la disciplina Biologie; determinarea valorilor motivației pentru învățare a liceenilor la disciplina Biologie prin instrumentele TIC; stabilirea aspectelor metodologice și elaborarea modelului de valorificare a instrumentelor TIC în contextul dezvoltării motivației pentru învățare a liceenilor la disciplina Biologie; fundamentarea metodologiei de valorificare a instrumentelor TIC în contextul dezvoltării motivației pentru învățare a liceenilor la disciplina Biologie; validarea eficacității pe cale experimentală a modelului de valorificare a instrumentelor TIC în contextul dezvoltării motivației pentru învățare a elevilor liceeni la disciplina Biologie.

Noutatea și originalitatea științifică se axează pe justificarea conjuncturii dintre instrumentele TIC, valorificate în procesul educațional la biologie și acțiunea acestora asupra motivației învățării elevilor liceeni în baza *Modelului de valorificare a instrumentelor TIC în contextul dezvoltării motivației pentru învățare a liceenilor la disciplina Biologie.*

Rezultatele obținute care contribuie la soluționarea problemei științifice rezidă în stabilirea reperelor științifice și metodologice de aplicare a tehnologiilor informaționale și comunicaționale în procesul didactic cu rezultate benefice asupra motivației pentru învățare a elevilor liceeni fapt ce a condus la elaborarea *Modelului de valorificare a instrumentelor TIC în contextul dezvoltării motivației pentru învățare a liceenilor la disciplina Biologie* și a metodologiei de implementare a lui care a contribuit la soluționarea coerenței dintre valorificarea instrumentelor TIC și mărirea valorilor motivației pentru învățare a elevilor liceeni la disciplina biologie cât și la eficientizarea procesului didactic la această disciplină școlară.

Semnificația teoretică constă în determinarea noilor puncte de vedere asupra posibilităților de consolidare a tehnologiilor informaționale și comunicaționale cu modalitățile de stimulare a motivației pentru învățare din perspectiva procesului didactic la biologie în învățământul liceal; în baza conceptelor praxiologice și validarea *Modelului de valorificare a instrumentelor TIC în contextul dezvoltării motivației pentru învățare a liceenilor la disciplina Biologie*, se propun repere metodologice, strategii de implementare, concluzii și recomandări care pot duce la formularea unor noi obiective pe domenii înrudite de cercetare.

Valoarea aplicativă a lucrării rezultă în metodologia elaborată pentru aplicarea *Modelului de valorificare a instrumentelor TIC în contextul dezvoltării motivației pentru învățare a liceenilor la disciplina Biologie* și mărirea complexului instructiv-metodic la disciplina Biologie care se implementează în mai multe licee din Republica Moldova urmare a cursurilor de formare continuă a cadrelor didactice referitor la integrarea TIC în procesul didactic la Biologie; a fost elaborat *Ghidul de implementare a tehnologiei STEM și utilizare a senzorilor în domeniul Științe ale naturii (din perspectiva Biologiei*); a fost lărgit spectrul de instrumente digitale care pot fi aplicate la lecțiile de Biologie (de exemplu, *revista online Ritm ProBiologic* care promovează caracterul atractiv și motivațional al științei Biologia).

Implementarea rezultatelor științifice obținute s-a realizat pe două dimensiuni: (1) desfășurarea experimentului pedagogic în cadrul IP Liceul Teoretic „Alecu Russo", s. Cojușna, raionul Strășeni, timp de doi ani; (2) sesiuni de formare profesională continuă pentru cadrele didactice de biologie, organizate de către Centrul de Formare Profesională Continuă UST (etapa preliminară) și de către AO „Inovație în Educație de Performanță", RM.

АННОТАЦИЯ

Плачинта Даниела

Использование средств ИКТ в дисциплине Биология в контексте развития мотивации обучения у лицеистов

Диссертация степени доктора педагогических наук. Кишинев, 2025

Структура диссертации: Диссертация включает введение, за которым следуют 3 главы, содержащие 49 рисунков и 19 таблиц, в том числе, выводы и рекомендации, 117 страниц основного текста, библиографию, представленную 219 источниками, 6 приложения. На основе результатов исследования по теме диссертации опубликовано 40 научных работ.

Ключевые слова: использование средств ИКТ, мотивация к обучению, среднее школьное образование, дидактика биологии, педагогическая модель, методика, педагогический эксперимент, валидация педагогической модели.

Цель работы: разработка теоретической и методологической основы реализации Модели ориентирована на использование средств ИКТ в дисциплине Биология, с целью повышения учебной мотивации старшеклассников.

Задачи исследования: определение психологических особенностей обучения старшеклассников; выявление ресурсов ИКТ и их применимости в дидактическом процессе по дисциплине «Биология»; определение значений мотивации обучения старшеклассников по предмету «Биология» средствами ИКТ; установление методологических аспектов и разработка модели использования инструментов ИКТ в контексте разработки мотивации обучения лицеистов по предмету Биология; обоснование методологии использования инструментов ИКТ в контексте разработки мотивации обучения лицеистов по Биологии; подтверждение экспериментальной эффективности модели использования инструментов ИКТ в контексте развития мотивации к обучению лицеистов по Биологии.

Научная новизна и оригинальность заключается в обосновании связи между средствами ИКТ, используемыми в образовательном процессе по биологии, и их воздействием на мотивацию обучения старшеклассников на основе *Модели использования средств ИКТ в контексте формирования мотивации обучения старшеклассников по предмету биология*.

Полученные результаты, способствующие решению научной проблемы, заключаются в установлении научно-методических ориентиров применения информационно-коммуникационных технологий в учебном процессе с положительным воздействием на учебную мотивацию учащихся старших классов, что привело к разработке *Модели использования средств ИКТ в контексте формирования учебной мотивации учащихся старших классов по предмету Биология,* и методики ее реализации, что способствовало разрешению взаимосвязи между использованием средств ИКТ и повышением значений учебной мотивации учащихся старших классов по предмету „Биология".

Теоретическая значимость состоит в определении новых точек зрения на возможности объединения информационно-коммуникационных технологий со способами стимулирования мотивации к обучению с точки зрения процесса обучения биологии в средней школе; На основе праксиологических концепций и проверки Модели использования средств ИКТ в контексте формирования мотивации к обучению учащихся старших классов по дисциплине «Биология» предложены методические ориентиры, стратегии внедрения, выводы и рекомендации, которые могут привести к формулированию новых целей в смежных областях исследований.

Прикладная ценность работы заключается в разработанной методике применения *Модели использования средств ИКТ в контексте формирования мотивации к обучению учащихся лицеев по предмету Биология* и расширения учебно-методического комплекса по предмету Биология, которая внедряется в ряде лицеев Республики Молдова по итогам курсов повышения квалификации учителей по вопросам интеграции ИКТ в процесс обучения предмету Биология; разработано *Руководство по внедрению STEM-технологий и использованию сенсоров в области естественных наук (с точки зрения биологии)*; Расширился спектр цифровых инструментов, которые можно применять на уроках биологии (например, *интернет-журнал Ritm ProBiologic*, пропагандирующий привлекательную и мотивирующую природу биологической науки).

Реализация полученных научных результатов осуществлялась в двух направлениях: (1) проведение педагогического эксперимента в рамках Теоретического лицея ИП «Алеку Руссо», с. Кожушна, Страшенский район, сроком на два года; (2) курсы повышения квалификации учителей биологии, организованные Центром Повышения Квалификации Педагогических Работников ТГУ (предварительный этап) и ОО „Inovație în Educație de Performanță" РМ.

ANNOTATION

Placinta Daniela

Use of ICT Tools in the Biology Subject in the Context of Developing High School Students' Motivation for Learning

Doctoral Thesis in Education Sciences. Chișinău, 2025

Thesis structure: The thesis includes the introduction, followed by 3 chapters in which are found: 49 figures and 19 tables, including, conclusions and recommendations, 117 pages of basic text, bibliography represented by 219 sources, 6 annexes. Based on the research on the topic of the thesis, 40 works were published.

Keywords: use of ICT tools, motivation for learning, high school education, Biology teaching, pedagogical model, methodology, pedagogical experiment, validation of the Pedagogical Model.

Purpose of the research: development of the theoretical and methodological basis for the implementation of the Model focused on the use of ICT tools in the Biology subject, in order to increase the learning motivation of high school students.

Research objectives: determining the psychological characteristics of high school students for learning; identifying ICT resources and their applicability in the teaching process in the Biology subject; determining the values of high school students' motivation for learning in the Biology subject through ICT tools; establishing methodological aspects and developing a Model *for using ICT tools in the Biology subject in the context of developing high school students' motivation for learning*; substantiating the Methodology *for using ICT tools in the Biology subject in the context of developing high school students' motivation for learning;* experimentally validating the effectiveness of the Model for using ICT tools in the Biology subject in the context of developing high school students' motivation for learning.

The scientific novelty and originality focus on justifying the connection between ICT tools, used in the Biology educational process, and their action on the learning motivation of high school students based on the *Model for using ICT tools in the Biology subject in the context of developing high school students' motivation for learning*.

The results obtained that contribute to solving the scientific problem reside in establishing scientific and methodological benchmarks for applying information and communication technologies in the teaching process with beneficial results on the learning motivation of high school students, which led to the development of the Model *for using ICT tools in the Biology subject in the context of developing high school students' motivation for learning* and its implementation Methodology, which contributed to resolving the coherence between the use of ICT tools and increase of the learning motivation values of high school students in the Biology subject, as well as to make the teaching process more efficient in this school subject.

The theoretical significance consists in determining new points of view on the possibilities of consolidating information and communication technologies with ways to stimulate motivation for learning from the perspective of the Biology teaching process in high school education; based on praxiological concepts and the validation of the Model *for using ICT tools in the Biology subject in the context of developing high school students' motivation for learning*, there are proposed methodological benchmarks, implementation strategies, conclusions and recommendations that may lead to the formulation of new objectives in related research areas.

The applied value of the research results in the Methodology developed for the application of the Model *for using ICT tools in the Biology subject in the context of developing high school students' motivation for learning* and the increase of the instructional-methodological complex in the Biology subject, which is implemented in several high schools in the Republic of Moldova following the continuing education courses for teachers on the integration of ICT in the Biology teaching process; There was developed the *Guide for the implementation of STEM technology and the use of sensors in the field of Natural Sciences (from the perspective of Biology)*; there was expanded the spectrum of digital tools that can be applied to Biology lessons (for example, the online *ProBiologic Rythm* journal which promotes the attractive and motivational nature of Biology science).

PLACINTA DANIELA

USE OF ICT TOOLS IN THE BIOLOGY SUBJECT IN THE CONTEXT OF DEVELOPING HIGH SCHOOL STUDENTS' MOTIVATION FOR LEARNING

SPECIALITY 532.02. SCHOOL DIDACTICS ON EDUCATION LEVELS AND SUBJECTS (Biology)

Summary of PhD Thesis in Education Sciences

Approved for publishing: 07.03.2025 Paper format 60×84 1/16
Paper offset. Type offset. Print run 50 copies
Pattern printed sheets: 2,1 Order nr. 56

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