PLOVDIV UNIVERSITY
„PAISII HILENDARSKI“
FACULTY OF MATHEMATICS AND INFORMATICS
DEPARTMENT OF EDUCATION IN MATHEMATICS, INFORMATICS, AND INFORMATION TECHNOLOGIES.

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USE OF INFORMATION TECHNOLOGIES FOR IMPLEMENTATION OF INTERDISCIPLINARY CONNECTIONS IN NATURAL SCIENCES EDUCATION IN PRE-GYMNASIUM LEVEL.

ABSTRACT

DISSERTATION

for the award of the educational and scientific degree of 'Doctor'
Field of higher education: 1. Pedagogical Sciences
Professional direction: 1.3. Pedagogy of Teaching…
Doctoral program: Methodology of Teaching in Informatics and Information Technologies.

SCIENTIFIC SUPERVISOR: **PROF. KOSTA GAROV**

Plovdiv, 2023

"The dissertation has been discussed and proposed for defense at an extended meeting of the Department of Mathematics, Computer Science and Information Technology Education at the Faculty of Mathematics and Informatics of Plovdiv University 'Paisii Hilendarski'.

The dissertation consists of 184 pages, of which 164 are in the main part, containing: Introduction, 3 chapters, 12 pages of used literature, and 3 appendices totaling 18 pages. The used literature includes 101 titles of articles and books and 32 internet sources. The cited articles and books are 63 in Cyrillic and 38 in Latin script.

The list of author's publications related to the dissertation consists of 6 titles. The publications have been cited 3 times.

The defense of the dissertation will take place on on 14.02.2024 at 11:00 a.m in the Conference Hall of the New Building of Plovdiv University 'Paisii Hilendarski'. The materials for the defense are available to those interested at the secretariat of the Faculty of Mathematics and Informatics, New Building of Plovdiv University, office 330, every working day from 8:30 am to 5:00 pm.

Academic jury:

Chairman:

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Title: Use of Information Technologies for Implementation of Interdisciplinary Connections in Natural Sciences Education in Pre-Gymnasium Level

Circulation: 30 copies.

Plovdiv, 2023

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INTRODUCTION

Relevance of the problem

The integration of information technologies with other academic disciplines is identified as a real necessity. This is a means to expand the possibilities and quality of education, a way for methodical enrichment of the teacher, which allows for solving the tasks currently faced by society as a whole.

The realization of interdisciplinary connections between information technologies and natural sciences helps students to develop a full understanding of natural phenomena and the connection between them, making the knowledge practically significant and applicable in life. **The object of the dissertation is** the use of information technologies for the implementation of interdisciplinary connections in the education of natural sciences in pre-gymnasiums.

The object of research is the level of knowledge, skills, and competencies in natural sciences (Man and Nature, Chemistry, and Environmental Science classes) of students in the lower secondary level (5th-7th grade) in primary school.

The main goal of the dissertation is to create an interdisciplinary methodological model for teaching natural sciences in the 5th, 6th, and 7th grades of primary school, which aims to increase the effectiveness of educational activities through the use of interdisciplinary connections between IT and natural sciences.

1. For the realization of the main goal, **the following tasks of the dissertation** research have been formulated: Justification of the relevance of the problem formulated in the present dissertation, including:

- Conducting a general review of the current set of educational and regulatory documentation related to the teaching of IT in the pre-gymnasium stage of education, and examining the possibilities for integrating current ICTs in science classes for successful implementation of interdisciplinary connections.
- Clarifying the positive and negative effects of applying ICT in the education of natural sciences in primary schools and the directions for overcoming the negative effects and the resulting problems.
- Researching the current state of the level of achievements of Bulgarian students, hourly teaching hours, and the qualifications of IT teachers in an international context.
- Clarifying the main concepts and research methods related to the current dissertation.

2. Developing an interdisciplinary methodological model for teaching natural sciences with the application of IT at the pre-gymnasium stage of education.

- Description of a technological model for implementing interdisciplinary connections in the education of natural sciences in pre-gymnasiums using IT.
- Analyzing the advantages of the system of educational materials for teaching natural sciences using cloud technologies, innovative educational applications, websites, and platforms.
- Justification of the methods, didactic techniques, and their impact on students in the teaching of natural sciences with the application of IT.
- Specific examples from the implementation of lesson units in natural sciences classes, revealing the role of interdisciplinary connections for the effective assimilation of the study material.

3. Conducting a pedagogical experiment to test the main hypothesis formulated in the current dissertation, analysis and interpretation of the obtained results, formulation of conclusions.

- Presentation and justification of the organization of the pedagogical experiment.
- Conducting a preliminary (preparatory) pedagogical experiment, analysis and interpretation of the obtained results.
- Conducting a formative pedagogical experiment.
- Comparative analysis and interpretation of the results obtained during the conduct of the formative pedagogical experiment.
- Testing the hypothesis and formulating conclusions from the conducted pedagogical experiment.

Hypothesis of the Study

The education in natural sciences in 5th, 6th, and 7th grades (extracurricular activities, interest-based classes), implemented according to the teaching methodology proposed in the current dissertation, which is based on the use of interdisciplinary connections between information technologies and natural sciences, would lead to an improvement in the quality of the educational process and the effectiveness of the education of students at the pre-gymnasium stage of primary education.

Methods of evaluation

To achieve the goals and tasks in this study and to test the hypothesis, the following methods were used:

- Study of pedagogical, psychological, methodological, and educational literature related to the issues of the current dissertation research, to build the theoretical foundation of the study.
- Theoretical and empirical research methods such as observation, comparison, analysis, synthesis, modeling, theoretical generalizations, group discussions, conversations with active teachers in natural sciences, tests.
- Utilization of accumulated personal experience in teaching natural sciences and in teaching natural sciences with the application of IT for the implementation of interdisciplinary connections in Bulgarian primary school;
- Didactic experiment;
- Mathematical-statistical methods for processing experimental data;
- Use of an instrumentarium, including a system of tasks, tests, and examination tasks, to assess the knowledge and skills of the students.

Structure and Volume of the Dissertation Work

The dissertation consists of 184 pages, of which 164 are in its main part, containing: Introduction, 3 chapters, 12 pages of used literature, and 3 appendices totaling 18 pages. The used literature includes 101 titles of articles and books and 32 internet sources. The cited articles and books include 63 in Cyrillic and 38 in Latin. The list of author's publications in the dissertation consists of 6 titles. The publications have been cited 3 times.

In the **introduction**, the relevance of the problem, subject, object, goals, tasks, hypothesis, research methods, and the structure of the dissertation are presented.

In **Chapter** I, opportunities for using IT in the educational process are presented; the essence of the concept of "interdisciplinary connections" is clarified from a historical perspective and from a pedagogical aspect; the possibilities for the application of interdisciplinary connections in the educational process are discussed; the possibilities for integrating current ICTs into the teaching of natural sciences are examined; the main concepts and research methods related to the current dissertation are explained.

In **Chapter II**, the author presents the **interdisciplinary methodological model** for teaching natural sciences with the use of IT for grades 5, 6, and 7. The goals, tasks, and expected results at each stage of the proposed interdisciplinary model are developed and explained. Approaches, methods, and tools for their implementation in classroom hours and extracurricular activities in the primary stage of basic education are provided. Projects/practices are proposed, implemented according to the model, and tested in grades 5, 6, and 7.

Chapter III includes the development of criteria and indicators for diagnosing the results of the pedagogical experiment. Preparation for conducting a pedagogical experiment to test the effectiveness of the proposed interdisciplinary teaching model for natural sciences in grades 5, 6, and 7 is carried out. A pedagogical experiment is conducted to test the effectiveness of the proposed interdisciplinary model, and the results of the effectiveness test of the teaching model are statistically processed and analyzed. Conclusions and findings are formulated.

In the **Appendix**, tests used for teaching and assessment are presented.

CHAPTER I. THEORETICAL FOUNDATIONS OF THE RESEARCH PROBLEM

1. Information Technologies in Education

1.1.It as a field of study

Teaching in Bulgarian schools is carried out according to standards defined by the Ministry of Education. The State Educational Standard for general education sets requirements for the outcomes of education in each subject and defines the competencies - knowledge, skills, and attitudes expected as results of education in each subject at the end of each stage of the corresponding level of education [40]. Specifically for education in computer modeling and information technologies, there is a separate document - Annex No. 5 to Art. 6, item 5 (New - SG, issue 79 of 2020) [41], and for education in information technologies - Annex No. 7 [42].

The pedagogical research conducted for the purposes of this dissertation study was carried out during the 2019/2020, 2020/2021, and 2021/2022 school years. During these academic years, Ordinance No. 5 of November 30, 2015, on general education was in force [40]. The curriculum for computer modeling and information technologies in the basic school for grades 5, 6, and 7, for which the methodological guidelines and toolkit presented in this dissertation study were developed, is provided in Annex No. 5 [41]. This gives grounds to assert that the developed methodological guidelines and toolkit presented in this dissertation study are relevant under the conditions of the current regulatory framework.

The inclusion of IT in educational programs leads to more modern, up-to-date, and practical education that meets the needs and interests of contemporary students [4], [5], [6], [7], [8], [9], [13], [16], [17], [18], [19], [34].

1.2. IT in the educational process

The digitization of education leads to a radical restructuring of the content and methods of teaching. Information technologies are integrated into the didactic system in various areas: they become new means for playful activities, intellectual, verbal, physical development of students, enrich communication between children and between them and the teacher with new content, enter the system with innovative and interactive teaching methods and techniques, and expand the scope and content of didactic tools.

There are various digital tools that support work in schools, including:

- Tools for cloud storage of information [27], [10].
- Tools for video conferencing
- Tools for creating presentations [3].
- Tools for gathering and presenting information [15], [38].
- Tools for creating digital grade notebooks [3].
- Tools for building websites.
- Tools for working with whiteboards.
- Tools for creating tests and surveys [21].
- Others [20], [32], [33], [11].

2. Interdisciplinary connections

2.1. Pedagogical aspects of the concept

In the pedagogical dictionary, interdisciplinary connections are interpreted as the mutual coordination of educational programs, determined by the system of science and didactic goals. There are numerous publications related to the justification of this concept [2], [3], [12], [20], [28], [29], [30], [37]. The conclusion drawn from all of them is that interdisciplinary connections help create a more comprehensive and interdisciplinary educational program that reflects the real needs of students. This leads to greater student engagement in the learning process by allowing them to study topics related to their interests and with real-life applications.

2.2. Opportunities for implementation of interdisciplinary connections between IT and matural sciences, studied in lower secondary education

The interdisciplinary connections applied in teaching natural sciences using IT serve as a means to activate students' cognitive activities. The variety of student activities can be grouped into three categories:

- Drawing definitions and arguments from related subjects using IT to expand the practical application of the theory studied in natural sciences (e.g., human and nature, biology, and chemistry).
- Incorporating concepts learned in other academic disciplines by using digital applications to explore the facts studied in natural sciences.
- Utilizing the actual skills and abilities acquired in the study of information technology to obtain new experimental data and information.

RESULTS OF CHAPTER I:

- A comprehensive review of the current set of educational and regulatory documents related to IT education in Bulgarian schools has been conducted. This review aims to ensure that the educational materials and regulations are up to date and aligned with the latest developments in the field of information technology.
- Possibilities for using IT in the educational process are presented
- The essence of the concept of "interdisciplinary connections" is clarified from a historical and pedagogical perspective.
- The possibilities for applying interdisciplinary connections in the educational process are explored.

- The possibilities for integrating current information and communication technologies (ICT) into the teaching of natural sciences are examined.
- The fundamental concepts and research methods related to the current dissertation work are explained.

CHAPTER II. INTERDISCIPLINARY METHODICAL MODEL AND METHODICAL TOOLKIT FOR IMPLEMENTATION OF THE MODEL

Teaching the curriculum in natural sciences in grades 5, 6, and 7 offers great opportunities for using IT in the classroom. This chapter presents a model of innovative educational methodology based on the use of interdisciplinary connections. The main idea of the presented author's model is to improve the effectiveness of natural science education by utilizing the possibilities of information technologies.

1. Description of the interdisciplinary methodological model for teaching natural sciences with the use of IT

Improving the quality of education is directly related to the pedagogical technology chosen to achieve educational goals. The integration of new methods and technologies in the classroom is a guarantee of successful implementation of the interdisciplinary approach in education.

The developed model related to the implementation of interdisciplinary connections between natural sciences and information technologies, presented by the author of the dissertation, represents an organized and relatively stable configuration of the individual elements of the educational process [26]:

- Idea for creating interdisciplinary connections;
- Design of teaching units;
- Development of educational content;
- Creation of teaching materials;
- Teaching in a new way;
- Organization of teaching time;
- Assessment and measurement of achievements;
- Analysis and results of the applied innovation.

The model functions as a system, i.e., as an organized set of elements with specific and lasting relationships between them. The conceptual structure of the developed technological model and the connections between its individual components are schematically presented in **Figure 3**:

Figure. 3. Interdisciplinary methodical model

1.1. Step one: Idea for creating interdisciplinary connections

1.1.1. Emergence of an idea for creating interdisciplinary connections in education

The idea for creating interdisciplinary connections in education can arise from various sources, such as:

- Observing the interaction between different subjects and their real-world applications.

- Studying contemporary trends in education and discovering opportunities for integrating educational material.
- Analyzing students' needs and searching for ways to facilitate their learning through more effective integration of knowledge.

1.1.2. The implementation of the idea

When the idea of creating interdisciplinary connections arises, it can be implemented through various methods, including:

- Integrating different subjects into one lesson or project, where students can use their knowledge and skills from different subjects.
- Organizing interdisciplinary modules where students can study specific topics by using their knowledge from multiple subjects.
- Creating interdisciplinary projects or research where students can work in teams and apply their knowledge from different subjects to solve real-world problems.

1.2. Step Two: Designing Educational Units

Designing educational units is the second step of the interdisciplinary model. There are several possibilities for integrating the curriculum [35], [36], [31], namely:

- Parallel integration of the curriculum
- Infusion integration of the curriculum
- Multidisciplinary integration of the curriculum
- Transdisciplinary integration of the curriculum

1.3. Step Three: Developing Educational Content

Developing educational content is a process that requires time, resources, and planning. It involves creating structured educational materials to help students understand and absorb knowledge on a given topic. Here are the steps followed in developing educational content:

- Learning objectives
- Researching the topic
- Structuring the content
- Creating interactive elements
- Design and layout
- Editing and proofreading

1.4. Step Four: Creating Educational Materials

Creating educational materials requires planning, organization, and a methodical approach. Creating effective educational materials goes through the following stages:

- Needs analysis
- Defining objectives
- Clear content structure
- Incorporating various resources containing interactive elements
- Feedback and progress tracking
- Educational support and resources

Creating interactive and engaging educational materials is crucial in ensuring effective learning [1], [43], [21], [25], [44].

1.5. Step Five: Teaching in a New Way

Teaching in a new way involves innovative methods and approaches that focus on active student participation, the development of critical thinking, and the acquisition of knowledge through practical experience. Some teaching methods and ideas that can support innovative teaching include flipped classrooms, project-based learning, problem-based learning, STEM education, game-based learning, storytelling-based learning, and more.

1.6. Step Six: Organizing Class Time

The organization of class time is crucial for achieving optimal teaching effectiveness. It's important to balance the academic, social, and emotional needs of students.

1.7. Step Seven: Assessment and Measurement of Achievements

Methods and practices for assessing and measuring student achievements include formative assessment, summative assessment, authentic assessment, rubrics, feedback, self-assessment, peer assessment, process assessment, adaptive assessment, group work assessment, and periodic progress monitoring.

1.8. Step Eight: Analysis and Results of the Applied Innovation

The analysis and results of applying the interdisciplinary methodological model in education provide information that can be used to improve practices and expand successful innovations on a broader scale.

2. Sharing Innovative Practice

A practice related to the application of the interdisciplinary methodological model in the pre-gymnasium stage of basic education is shared. Over the course of three academic years (2020/2021, 2021/2022, and 2022/2023), she experimented with the interdisciplinary methodological model in basic education.

Seven examples of projects implemented using the interdisciplinary methodological model are shared in the dissertation. Four of them are presented in the abstract.

2.1. Project "Stargazing"

The project was created and implemented over two consecutive years. In December 2021, it involved five parallel classes of 5th-grade students (a total of 130 students) with mentors from the "Green Alternatives" club (7th grade). In February 2023, the project was carried out again, with the participation of five parallel classes of 5th-grade students (132 students) and mentors consisting of 20 students from 6th grade.

The project followed the steps of the interdisciplinary methodological model.

This interdisciplinary learning was implemented with fifth-grade students over a period of one month in the section "Physical Phenomena," subsection "Earth and Space," with lessons on "Starry Sky," "Our Star – the Sun," and "Our Neighbors – the Planets." The goals and expected outcomes are related to the conscious need for information, problem-solving in an uncertain and dynamic environment, and successful teamwork.

Knowledge and skills in information technology can be used when working with Mozaik 3D and Solar System Scope. These innovative educational software are used for visualizing topics

such as 'Solar System,' 'Starry Sky,' 'Space Exploration,' 'Our Natural Satellite – The Moon.' They create a virtual space where children can immerse themselves and explore a given problem. The interaction offered by these applications leads to increased motivation in natural sciences.

Biology and health education are linked to answering a problematic question related to the existence of life forms on other planets and forming hypotheses based on the essential conditions for life. Applications that can be used include Jamboard for teamwork on hypotheses. The virtual board allows students to simultaneously share opinions and hypotheses in the virtual space, making the communication in class exciting. Mozaik 3D and Solar System Scope are software that further illustrate the material in biology. Chemistry and Environmental Protection are included in determining the composition of different categories of stars, as well as in learning about the structure and composition of planets. Students work with the Solar System Scope application, which provides a large database related to stars, constellations, planets, and other cosmic objects. The subject of physics and astronomy is included in answering a problematic question related to gravitational force.

During the 2022/2023 academic year, the interdisciplinarity of education expands by including mathematics, Bulgarian language and literature, history and civilizations, geography and economics, and visual arts. The training becomes STEM and is in line with new trends in education.

In the subject of Bulgarian language and literature, students are assigned to write an essay on topics such as 'The Earth After 100 Years' or 'My First Spacewalk to Mars.' Students work individually using Google Docs.The shared document gives the students an opportunity to work simultaneously in one document, which saves time and gives opportunity for effective teamwork. The studied educational material in mathematics helps students in determining distances in light years, the number of constellations, drawing geometric figures on star charts, determining the diameter of planets, and the number of satellites. Digital applications suitable for this purpose are Google applications and Solar System Scope. Geography and economics as a science assist students in working with star and synoptic maps. The Solar System Scope application helps students in determining scale, distances, and other characteristics. In the subject of history and civilizations, topics such as the Big Bang theory, the age of stars, and their classification according to it are covered. Visual arts are included in the creation of projects, 3D models, sketches, drawings of stars, constellations, planets, comets, etc. Graphic editors (Paint 3D, GIMP) and innovative educational applications for virtual and augmented reality (Mozaik 3D, Smart Classroom AR) are used to assist students.

5th-grade students have the necessary skills to work with the mentioned applications and websites because they have studied topics such as 'Working with the Internet' (Solar System Scope, Mozaik 3D, Smart Classroom AR), 'Computer Text Processing' (Google Docs, Jamboard), 'Working with Graphic Editors' (Paint 3D, GIMP).

The beginning of the interdisciplinary education starts with a visit to the Planetarium at the Natural Science Museum in Plovdiv, visualizing stars, constellations, and planets of the Solar System with a 3D movie. The finale of the 'Looking at the Stars' project (Fig. 7) over the two academic years (December 2021 and February 10, 2023) involves organizing a celebration - a competition in the school among all fifth-grade parallel classes with mentors and organizers from the sixth and seventh graders of the 'Green Alternatives' club (a group for extracurricular activities in the school). The active participation, creativity of the students, and the knowledge, skills, and competencies they acquired are proof of the success of the interdisciplinary methodological model.

Фиг. 7. „Stargazing“

Provoking interest in the sciences, increasing motivation for learning, and successful realization in future professions are some of the main goals of education using the interdisciplinary methodological model.

2.2. Project “Green zone”

Fig. 8. Interdisciplinary methodical model, applied in project „Green zone”

The 'Green Zone' project was prepared and implemented following the interdisciplinary model ***(Fig. 8)***. It begins its implementation during regular class hours but continues during extracurricular activities (after-school activities). From interdisciplinary, it transforms into transdisciplinary, involving collaboration with other institutions. The author of the dissertation shares that this project is the most successful in attracting followers among classmates, parents, and institutions to causes related to nature conservation.

The planned duration for the implementation of the project is one month. The target group for the realization of the project are students in the lower secondary stage. It includes all natural sciences, mathematics, and technologies. The goal of the education is to develop ecological awareness in young students and instill a sense of care for nature through actions aimed at its

conservation and preservation. During the educational process, practical activities are included, leading to the acquisition of skills for caring for nature.

The subject of chemistry and environmental protection is included in the topics related to recycling and composting, as well as in choosing the appropriate fertilizers for different plant species. Biology and health education are involved in selecting types of plants, shrubs, and trees for greening the schoolyard. Knowledge and skills in geography and economics can be used in topics related to climate and precipitation. It is necessary to determine the locations for planting different plant species and to assess the frequency of their watering. The studied educational material in information technologies helps students in creating a text document (Google Docs) related to the 'Green Zone' theme, as well as in preparing a report for the necessary materials, consumables, and equipment, using electronic spreadsheets (Google Sheets). The creation of brochures and posters is made possible by the functionalities provided by the Canva application. And the preparation of reports and presentations, thanks to Google Slides, Canva, Slidesgo, etc. Knowledge in mathematics helps students in preparing a table with the necessary amount for the implementation of the project, as well as in calculations for making a 3D model. Skills acquired in the subject of technology and entrepreneurship are used for making 3D models of the project, aiming for better visualization and the possibility of clarity and accessibility.

Initially, the participants in the natural sciences club use the project to participate in a competition announced by the Ministry of Environment and Water (MOEW) and the Regional Inspectorate of Environment and Water (RIEW) as part of the National Campaign 'Clean Environment – 2021' on the theme 'I Love Nature - I Participate Too.' Partners in the initiative are the authors of the article and senior experts from the 'Ecology' department at the municipality.

Although the project did not win funding, the young environmentalists from the club continue to spread their ideas and cause. Working with other children in school, with parents, negotiating with the school management, analyzing, and researching, and the assistance of senior experts - ecologists, form ecological culture, ecological awareness, and ecological behavior in the students.

The enthusiasm of the young ecologists led to the participation of the entire school community in the implementation of a project related to the greening of the schoolyard. The result is the installation of 6 benches shaped like the letter S ***(Fig. 9)***, planting of 6 different types of trees, 150 shrubs forming a live fence, 200 plants of various species with bright colors adorning the yard, several relaxation zones with different grassy species, as well as placing bins for separate waste disposal

Fig. 9. Part of project "Green Zone"

The project continues into the next academic year (April 2022). On the occasion of Earth Day, the students (from the 6th grade and the 'Green Alternatives' club) decide to expand the green zone. By participating in projects, competitions, and contests, and attracting like-minded individuals including the school management, parents, and institutions (the 'Ecology' department of the Plovdiv Municipality, 'Parks and Gardens'), they manage to secure funds for purchasing an additional 3 benches, 100 shrubs, and 200 plants.

Parents as partners are informed about the students' causes through a website ***(Fig. 10)*** for communication, created and maintained by the participants from the 'Green Alternatives' club

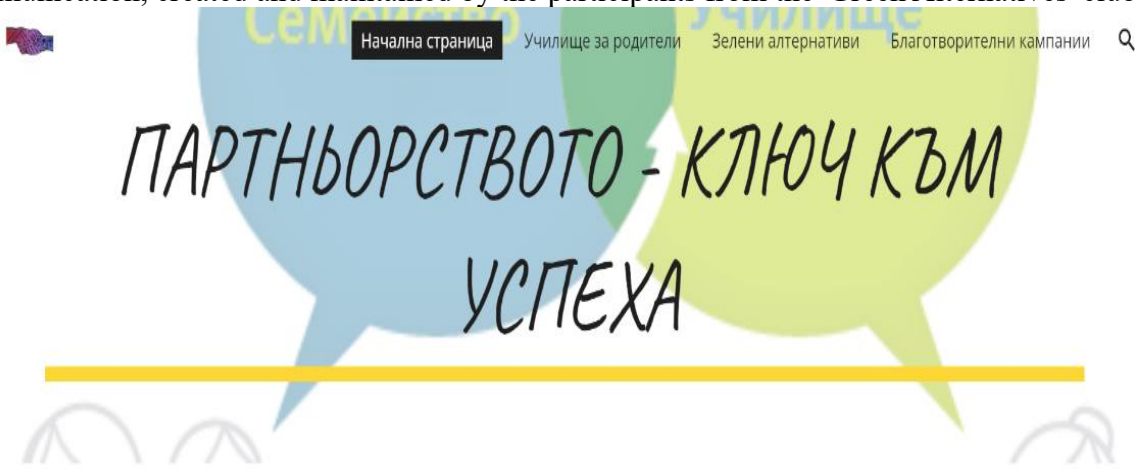

Fig. 10. Site for parents

This project could also be successfully implemented at the high school level, linking it with economics, business, accounting, natural sciences, and other subjects. This would demonstrate the applicability of the interdisciplinary methodological model in the high school stage of secondary education. The universality and successful application at different stages of education prove the contribution of the model to the development of interdisciplinary methodology.

2.3. Project “Air Pollution”

The transdisciplinary approach in the implementation of the 'Air Pollution' project is applied in the 5th grade classes of 'Man and Nature,' information technology, mathematics, visual arts, and in the 7th grade classes of chemistry and environmental protection, information technology, and mathematics, as well as in extracurricular clubs focused on natural sciences ***(Fig. 13)***.

The period for its implementation is two months. The goal of the education is to form an ecological consciousness in students and a belief in caring for nature through actions for its preservation and protection. During the educational process, practical activities of the students are included, leading to the acquisition of skills and competencies related to working with sensors, innovative educational software, data interpretation, model/mock-up creation, promoting beneficial practices, and acquiring 'green' competencies.

The project involves students from the lower secondary stage. The goal of this transdisciplinary education is for the students to jointly plan the initiatives, acquiring skills for effective time management, teamwork, and recognizing their own capabilities. Placed in a problematic situation, the learners learn to defend their positions, become ready for compromise, and develop communication skills in various environments, according to the author of the dissertation. The project was successfully implemented and tested during the natural sciences classes and extracurricular activities. It includes the knowledge, skills, and competencies of the students across several subjects.

The essence of the project consists of activities to measure the air pollution in the area around the school and measures to reduce it. The activities began with the presentation of the idea to the students, who were divided into teams. Each team started preparing to conduct a roundtable discussion on the problem and its solution with the participation of institutions involved in environmental protection. The preparation covered two weeks and included solving a real problem, which was linked to the competencies and skills of the students in natural sciences, information technology, mathematics, geography, and visual arts.

Natural sciences helped the students in determining air pollutants and sources of pollution. A study was conducted in relation to the area of the 'green zone' in the schoolyard and the need for a certain number and type of plant species associated with reducing air pollution. The knowledge and skills from the subject 'Man and Nature' were also involved in examining topics related to recycling and composting, as well as in choosing suitable fertilizers for different plant species. The studied educational material in information technology helps students in creating a text document (Google Docs) related to the theme, as well as in preparing a report for the necessary materials, consumables, and equipment, using electronic spreadsheets (Google Sheets). The creation of brochures and posters is made possible by the functionalities provided by the Canva application. And the preparation of reports and presentations, thanks to Google Slides, Canva, Slidesgo, etc. Knowledge in mathematics assists students in creating tables related to diagrams and calculations of air pollution in the school area. Skills acquired in the subjects of visual arts, technology, and entrepreneurship are used for making models of the pollutant molecules and devices related to the project, aiming for better visualization and the possibility of clarity and accessibility.

5th-grade students have the necessary skills to work with the mentioned applications and websites, as they have studied topics like 'Working with the Internet' (searching for information),

'Computer Text Processing' (Google Docs, Jamboard), 'Working with Graphic Editors' (Paint 3D, GIMP).

7th-grade students, who are mentors, have knowledge and skills in working with electronic spreadsheets (Google Sheets) and presentations (Google Slides, Canva, Slidesgo).

During the 'roundtable' discussion, which included representatives from the Energy Agency of Plovdiv (invited by the students), representatives from the 'Ecology' department of the local municipality, and parents, the idea emerged for the students to participate in the ***COMPAIR*** project ***(Fig. 14)*** [39]. A mobile laboratory for testing air quality was set up in the schoolyard. The students were introduced to the operation of the devices.


14 | ИМОТИ

ВЕСТНИК „МАРИЦА"

Ученици замерват праховите частици във въздуха

Fig. 14. Students start project COMPAIR

The students themselves assembled 'do-it-yourself' sensors for measuring particulate matter. In their extracurricular activity classes, they learned how a sensor works, recording the intensity of traffic – pedestrians, cyclists, and various types of vehicles, and a sensor allowing for static and dynamic measurement of particulate matter.

Sensors for particulate matter and traffic were mounted on the facade of the school, and the students were introduced to the software for recording and analyzing the collected data in their information technology classes and extracurricular clubs.

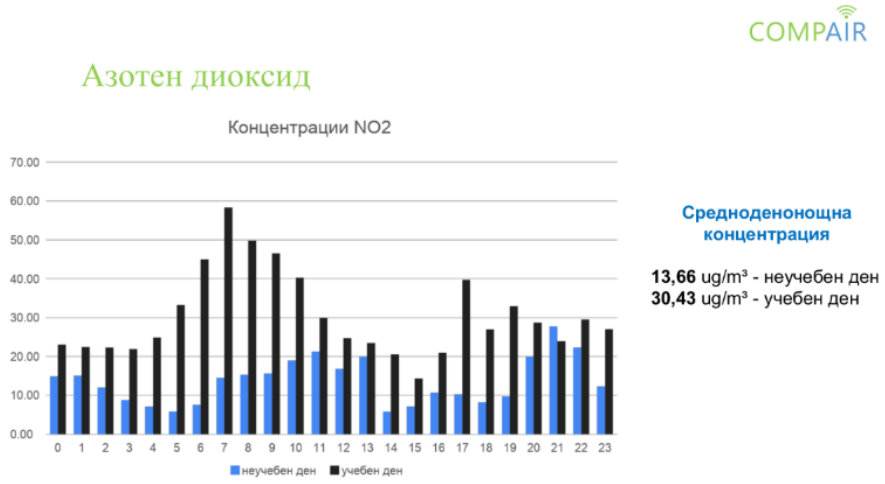

Fig. 15. Data on nitrogen dioxide concentration

By participating in these activities, the students had the opportunity to become familiar with various methods of measuring air quality, thus developing an attitude and behavior related to studying and conserving nature. In addition to 'green' competencies, students also develop digital competencies through experiments, research, and data analysis ***(Fig. 15)***. The project activities provide an opportunity to shape the students' understanding of the integrity of nature and the personal role of everyone in its conservation, according to the author of the dissertation.

The transdisciplinary education associated with the 'Air Pollution' project developed in students the skills and competencies to solve a real problem.

The goal of today's education is to develop individuals who are successful in life. Transdisciplinarity is the key to the effectiveness of education, according to the author of the dissertation.

2.4. Project "Structural Formulas – A Challenge for Seventh Graders"

Fig. 16. Interdisciplinary Methodological Model Applied to the Project 'Structural Formulas - A Challenge for Seventh Graders'

The goal of the project is to enhance the students' interest in mastering the knowledge and skills in the subject of Chemistry and Environmental Protection in the seventh grade. The lessons included are in the section 'Chemical Symbolism. Valency'.

The beginning of the transdisciplinary education is a project activity related to the structure of chemical compounds. For this, the class is divided into teams, and each one creates a 3D model. At this stage, the students are aided by their knowledge and competencies in chemistry, related to atomic particles, structure of substances, valency, and nomenclature. This model can be made from recycled materials (biology and health education) or with the help of ready-made kits (technology and entrepreneurship).

The goal of the second stage of the education is to add the created models as images in augmented and virtual reality applications and to create a lesson on the topic. The students use competencies related to information technologies for images, internet usage, and innovative software applications for VR and AR reality (Google Arts & Culture, Mozaik 3D, Augment Education, etc.).

The third stage of the project includes presenting the projects and lessons with augmented and virtual reality to students and teachers from the Chemistry Department of Plovdiv University 'Paisii Hilendarski'.

At this unique seminar, the idea arose to use software, aimed at facilitating the understanding of the concept of valency and the nature of the structural formulas of chemical compounds.

Such interactive software (ACD/ChemSketch) was tested (Fig. 17) in the chemistry and environmental protection classes of the 7th grade (June 2023). The software proved to be interesting and useful. It is planned to be used in classes during the next academic year (2023/2024) to aid in understanding abstract concepts in the subject of Chemistry and Environmental Protection in the seventh grade.

Fig. 17. 'Structural Formulas - A Challenge for Seventh Graders'

2.5. Project 'Healthy Eating' - Preparation and Conduct of a Seminar

The project ***(Fig. 11)*** involves students from the lower secondary stage. The goal set is for the students to jointly implement initiatives, acquire skills for effective time management, work as

a team, and identify their strengths and weaknesses in the project activity. Placed in a problematic situation, the learners learn to defend their positions, become ready for compromise, and develop communication skills in various environments, the teacher concludes. The project was successfully implemented and tested during the natural sciences classes and extracurricular activities. It includes the knowledge, skills, and competencies of the students across several subjects.

The project starts with the preparation of the seminar, which involves creating a program, invitations, posters, and brochures. The students' knowledge of information technology is applied in using applications for creating presentations (Google Slides, PowerPoint, Canva, Slidesgo), which contain a plan for preparing and conducting the seminar. The same applications assist in the creation of invitations, posters, and brochures.

At this stage of the project, the skills acquired from visual arts classes come in handy. The design, colors, choice of font, and images are important for attracting an audience and like-minded individuals.

The next step is selecting sub-topics related to the main theme 'Healthy Eating', which involves health knowledge and hygiene of the digestive, musculoskeletal, and excretory systems. This also includes diet and sports regimes, for which competencies acquired in biology and health education classes are used. Work is done with an online health calculator and virtual libraries. The choice of sub-topics is realized through the brainstorming method, as students generate ideas in a short period. The Popplet application is used to create mind maps. For the apps……

The competencies acquired in chemistry and environmental protection help students in identifying nutrients and the foods that contain them, as well as in determining the necessary vitamins and minerals. The Mozaik and Water Drink Reminder applications assist in the implementation of the project.

Mathematics helps students in calculating quantities and calories using an online health calculator.

The knowledge and skills acquired in Bulgarian language and literature classes are used by students in creating and editing the text for invitations, posters, and brochures. Presenting the prepared reports and projects to an audience during the seminar itself requires good presentation skills, which the students acquire in their classes.

Digital applications for creating reports, presentations, invitations, etc., are Google Docs, Google Slides, Canva, and Slidesgo. The students created their own website for the seminar, where they published their projects and the digital materials created by their classmates.

Evidence and further results from the extracurricular activities related to STEM education can be found on the 'Green Alternatives' club website ***(Fig. 12)***, on the website of the 'Dimitar Talev' Primary School in Plovdiv, and in internet media, shares the author of the dissertation.

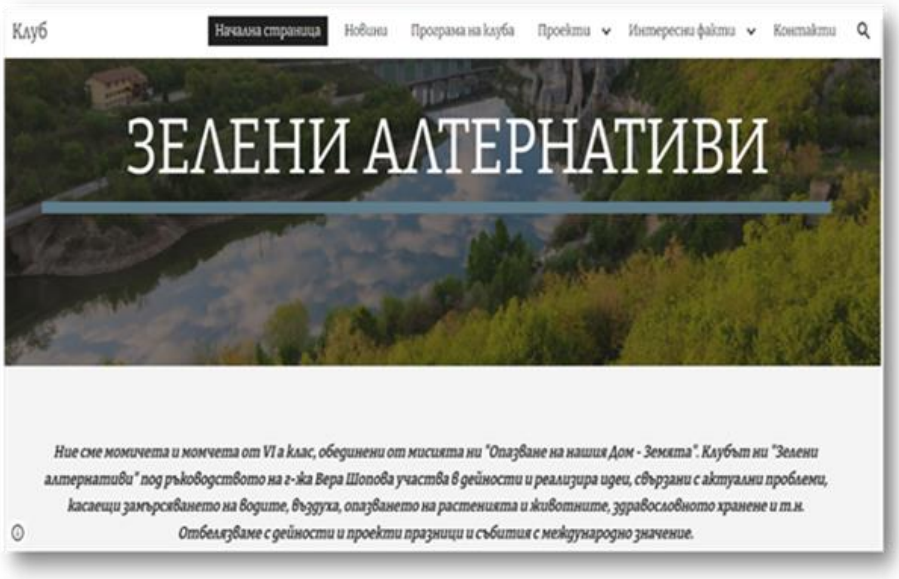

Fig. 12. Website for club "Green alternatives"

2.6. Water – The Source of Life

The project on the theme 'Water – The Source of Life' was prepared and implemented following an interdisciplinary model. It starts in the classroom but continues in extracurricular activities (after-school activities). From interdisciplinary project, it transforms into transdisciplinary one by involving work with other institutions.

The idea for the project emerged at the beginning of the 2020/2021 academic year, in connection with a planned celebration for World Water Day by natural science pedagogical specialists during a meeting of their key competency team (professional learning community). It was planned as interdisciplinary education, including natural sciences and information technology. The educational content and materials were developed by teachers of natural sciences and information technology. The period for the implementation of the interdisciplinary education according to the initial plan is one month. The target group for the realization of the project is students from the five parallel classes of the 6th grade. The goal of the education is to form an ecological consciousness in young students and instill a sense of care for nature through actions aimed at its conservation and protection. The entire educational process is conducted in an electronic environment remotely, using Google Apps (Classroom, Meet, Calendar, Docs, Slides, Jamboard, Sites).

For the training, the students were divided into 3 teams.

The first team had the task of taking interviews from individuals who support eco-ideas and inspire the students with their example.

The second team was assigned a project activity related to March 18 – World Recycling Day.

The third team was assigned a project activity related to March 22 – World Water Day.

The first team conducted a series of interviews, including experts from the 'Ecology' department at the Municipality, inspectors from the 2nd Regional 'Fire Safety and Population Protection' Service in Plovdiv, and the school's management. The videos were processed during the information technology classes.

The second and third teams spent 3 weeks working on their projects for Recycling Day (March 18) and Water Day (March 22). The projects included dresses, bags, hats, candle holders, fireplaces, pencil holders, 3D models, etc. The girls and boys painted T-shirts for Water Day. They created posters, brochures, invitations, covers for their virtual classrooms, games, and crosswords, using applications such as Canva, LearningApps, Slidesgo, Wordwall, Google Sheets, presentations, and documents. The videos were processed during the information technology classes. The knowledge was acquired by the students from the topics 'Video and Sound'. All of this was uploaded to their website by the 'Green Alternatives' club members [108].

The finale of the project activity was a celebration-competition on the occasion of Water Day under the slogan 'The Future is in Our Hands!'. It was held on March 22 using Meet, due to the declared pandemic. Official guests included representatives from the 'Ecology' department and inspectors from the 2nd Regional 'Fire Safety and Population Protection' Service in Plovdiv. The students were also supported by the school management. Students have the knowledge and skills to work with Google Apps, due to the personal accounts created by the educational organization, which has the status of a 'School in the Cloud,' as well as from the topics studied in IT classes such as 'Working with the Internet,' 'Electronic Mail,' 'Video and Sound'.

The online celebration lasted two hours and was conducted in 3 rounds, with students from all parallel classes of the 6th grade in our school participating.

In addition to presenting the products of their project activity, the students demonstrated knowledge and competencies related to working in an online environment.

The 'Water – The Source of Life' project was conducted for 7th-grade students in the 2021/2022 academic year and for 5th-grade students in the 2022/2023 academic year. Information about the project and the results of the training for teachers and students have been published on the website of 'Dimitar Talev' Primary School, Plovdiv.

The examples of training using the interdisciplinary methodological model given in section 2 were conducted during class hours and extracurricular activities and cover 30% of the educational material for the subjects 'Man and Nature' (5th and 6th grade), 'Information Technologies' (5th - 7th grade), and 'Chemistry and Environmental Protection' (7th grade).

The increase in learning outcomes over the last three academic years in natural sciences and information technologies, the increase in the number of participants in natural science clubs, the engagement of the school community and institutions, the scale of events, and the causes organized by students are factors that determine the success of the interdisciplinary methodological model. Surveys for feedback, discussion forums, and seminars conducted among teachers and students are proof of the success of the implemented innovation.

Evidence and results from the work of teachers and students can be found on the school's website [45], the Energy Agency of Plovdiv's page [39], internet media, and in the appendices to the dissertation.

RESULTS OF CHAPTER II:

- An interdisciplinary methodological model for teaching natural sciences with the application of IT for 5th, 6th, and 7th grades has been proposed.
- The objectives, tasks, and expected results of each stage of the proposed interdisciplinary model have been developed and explained, and approaches, methods, and means for their implementation in class hours and extracurricular activities in the lower secondary stage of basic education have been provided.

- Projects /shared practices/ implemented according to the model and tested in 5th, 6th, and 7th grades have been proposed.

CHAPTER III. ORGANIZATION AND CONDUCT OF PEDAGOGICAL RESEARCH

The dissertation presents the results of three independent pedagogical studies. One is conducted in the subject 'Man and Nature' in the 5th grade. The second is conducted in the subject 'Man and Nature' in the 6th grade. The last one is conducted in the subject 'Chemistry and Environmental Protection' with 7th-grade students.

The organization and conduct of pedagogical research include several important stages that are key to its successful implementation and the obtaining of quality results. These stages are as follows::

- Defining the problem and formulating research questions;
- Determining research methods;
- Selecting researchers and participants in pedagogical research;
- Collecting data for pedagogical research;
- Analyzing the data;
- Formulating conclusions.

1. Defining the Problem and Formulating Research Questions

The problem of the pedagogical research is related to the effectiveness of natural sciences education at the lower secondary education stage when interdisciplinary connections between information technologies and natural sciences are used.

The questions in the pedagogical research are related to the material studied by the students in natural sciences in the 5th, 6th, and 7th grades.

2. Determining the Research Methods

The chosen test method allows for the collection of quantitative data that can be statistically analyzed. This enables researchers to draw conclusions and make objective assessments of the differences in results between the experimental and control groups.

The traditional structure of conducting a pedagogical experiment (three stages) was followed:

- Preliminary (diagnostic) experiment, related to the determination of the criteria and indicators of the research; development of verification tests and tasks; development of a model for quantitative analysis of empirical data; formation of samples and groups.
- Processual (formative) experiment, associated with training according to the proposed methodology and educational content; conducting test examinations and control exercises;
- Final experiment, related to the analysis of the qualities of the tests; analysis and presentation of the obtained results; formulation of conclusions and hypotheses.

The purpose of the diagnostic experiment is to provide information about the preliminary achievements of the students on the studied educational content [46]. During the training with the

proposed methodology, control over the intermediate results of its application was carried out. The final test was conducted at the end of the research period.

3. Selection of Researchers and Participants in Pedagogical Research

The pedagogical research was conducted by the author of this dissertation. The author possesses the necessary qualifications, experience, and expertise in the field of pedagogy and education.

The research involved a representative sample of:

- 100 students from 5th grade regular education, divided into 2 groups of 50 students each – experimental (exp) and control (con);
- 100 students from 6th grade regular education, divided into 2 groups of 50 students each – experimental (exp) and control (con);
- 100 students from 7th grade regular education, divided into 2 groups of 50 students each – experimental (exp) and control (con).

In total, 300 students from 'Dimitar Talev' Primary School in Plovdiv participated in the study. The assessment of knowledge and skills was conducted through tests covering the educational content of the subjects:

- 'Natural studies' for students from 5th and 6th grades
- 'Chemistry and Environmental Protection' for students from 7th grade

4. Formulating Conclusions

The objective information obtained from processing the results of the conducted pedagogical research is an example showing that the teaching of natural sciences in the 5th, 6th, and 7th grades (main curriculum, extracurricular activities), implemented according to the methodology proposed in this dissertation, which is based on the use of interdisciplinary connections between information technologies and natural sciences, leads to an improvement in the quality of the educational process and the effectiveness of teaching students at the lower secondary stage of basic education.

RESULTS FROM CHAPTER III

- Criteria and indicators for diagnosing the results of the pedagogical experiment have been developed.
- Preparation for conducting a pedagogical experiment to verify the effectiveness of the proposed interdisciplinary model for teaching natural sciences in the 5th, 6th, and 7th grades was carried out.
- A pedagogical experiment to verify the effectiveness of the proposed interdisciplinary model was conducted.
- The results of the effectiveness check of the educational model have been statistically processed and analyzed. Conclusions and findings have been formulated.

SUMMARY

It can be concluded that the goal of the dissertation has been achieved with the development and approval of the proposed interdisciplinary model.

The hypothesis of the dissertation is defended, i.e., the teaching of natural sciences in the 5th, 6th, and 7th grades (main curriculum, extracurricular activities), implemented according to the model proposed in this dissertation, based on the use of interdisciplinary connections between information technology and natural sciences, leads to an improvement in the quality of the educational process and the effectiveness of teaching students in the lower secondary stage of basic education

As mentioned in Chapter 1, current curricula in information technology, as applied in Bulgarian primary schools, encourage the use of IT capabilities to support and enhance the effectiveness of the educational process in natural sciences. Despite the guidance provided by these curricula, there is a lack of developed methodological instructions and didactic materials for the application of IT in the actual process of teaching natural sciences.

In response to this issue, the current dissertation has developed and presented an interdisciplinary methodological model for teaching natural sciences using IT in primary schools. Each step of the model is thoroughly explained and viewed from all perspectives (of both the educator and the learner). The advantages of the system of educational materials for teaching natural sciences with the help of cloud technologies, innovative educational applications, websites, and platforms are analyzed. A detailed justification of the methods, didactic approaches, and their impact on students in the teaching of natural sciences using IT is provided. Specific authorial examples from the implementation of lesson units in natural sciences classes are presented, revealing the role of interdisciplinary connections for the effective assimilation of the educational material.

After conducting the pedagogical experiment that examined the influence of implementing the interdisciplinary methodological model in practice on students' achievements, the positive effect of integrating IT into traditional teaching methods of natural sciences in primary school was categorically proven.

PERSPECTIVES FOR FUTURE DEVELOPMENT

The dissertation can be used, expanded, and continued in the following aspects:

- Creating a system of lessons using the interdisciplinary methodological model in natural sciences and other subjects (social sciences, mathematics, technology and entrepreneurship, arts);
- Publishing the created lessons as resources on the Ministry of Education and Science's 'Digital Backpack' platform;
- Creating STEM lessons according to the model to be implemented in STEM centers [40].
- Conducting teacher training to prepare them for the application of the interdisciplinary methodological model;
- Developing a methodological guide with instructions and educational resources to assist teachers who will work with the interdisciplinary methodological model;

- Ideas for providing material equipment in classrooms with the necessary digital technologies for working with the interdisciplinary methodological model;
- Developing and expanding the model through the use of artificial intelligence capabilities.

MAIN CONTRIBUTIONS OF THE DISSERTATION

The main goals and tasks of the dissertation research have been achieved. The main contributions of the dissertation can be characterized as scientific-applied and practical.

Scientific-applied contributions of the dissertation research are:

SA1. An original interdisciplinary methodological model has been developed for implementing interdisciplinary connections between natural sciences and IT in the educational process.

SA2. Methods and didactic approaches have been proposed for the successful implementation of the proposed interdisciplinary model.

Practical contributions of the dissertation research are:

P1. Original projects using the interdisciplinary methodological model have been developed, which can be directly applied in pedagogical practice;

P2. A pedagogical experiment has been conducted to determine the effectiveness of the interdisciplinary methodological model. The processing of the obtained results confirms the hypothesis of the dissertation.

The connection between the contributions, tasks, their description in the dissertation, and the publications made are shown in Table 27..

Contribution	Tasks	Chapter	Publications
Scientific-applied			
SA1	2	Chapter 2, point 1, page 43.	5
SA2	2	Chapter 2, point 1, subpoints 1.3 и 1.4, page 54.	1, 2
SA3	2	Chapter 2, point 1, subpoints 1.5, 1.6, 1.7 и 1.8, page 74.	3
Practical			
P1	2	Chapter 2, point 2, page 89.	4, 6
P2	3	Chapter 3, page 110.	

Table 27. Connections between the contributions, tasks, their description in the dissertation, and the publications made

REFERENCES FOR PUBLICATIONS ON THE TOPIC OF THE DISSERTATION

Publications in journals:

1. Shopova, V., Dimitrov, I. (2021), The Place of Augmented Reality in the Educational Process, Journal "Education and Technology", Volume 12, Issue 1, 244-248 pp., ISSN 2535-1214.
2. Shopova, V. (2021), Interactivity - Key to Successful Education, SMB, Volume of Reports, 337-341 pp., ISSN 1313-3330.
3. Shopova, V., Gurov, K. (2022), Encouraging Ecological Education in Interest Clubs, Journal "Education and Technology", Volume 13, Issue 1, 201-205 pp., ISSN 2535-1214.
4. Shopova, V., Velcheva, Iv. (2022), Sharing Innovations - Key to Successful Education, Journal "Education and Technology", Volume 13, Issue 2, 170-173 pp., ISSN 2535-1214.
5. Shopova, V., Dimitrov, I. (2023), Interdisciplinary Methodological Model, Journal "Education and Technology", Volume 14, Issue 2, 284-290 pp., ISSN 1314-1791 (print), ISSN 2535-1214 (online).
6. Shopova, V., Velcheva, Iv. (2023), Transdisciplinarity - Key to an Effective Educational Process, Journal "Education and Technology", Volume 14, Issue 1, 175-179 pp., ISSN 1314-1791 (print), ISSN 2535-1214 (online).

Presented reports:

1. Report on the topic "Promoting Environmental Education in Interest Clubs," National Scientific and Practical Forum with International Participation "Innovations in Education and Cognitive Development," August 17-19, 2022, in Burgas, Bulgaria.
2. Report on the topic "Interdisciplinary Methodological Model," XIV Scientific and Practical Forum "Innovations in Education and Cognitive Development," August 23-25, 2023, in Burgas, Bulgaria.
3. Report on the topic "Transdisciplinarity - the Key to an Effective Educational Process," XIV Scientific and Practical Forum "Innovations in Education and Cognitive Development," August 23-25, 2023, in Burgas, Bulgaria.

NOTED CITATIONS

Cited article:

Shopova, V. (2021), Interactivity - the Key to Successful Education, SMB, Reports Volume, pp. 337-341, ISSN 1313-3330.

From:

1. Velcheva, I., Dimitrov, I. (2023) EDUCATIONAL GAME IN SCRATCH RELATED TO THE SUBJECT "MAN AND NATURE" FOR 4TH GRADE, "Education and Technology" Journal, Volume 14, Issue 1, pp. 222–228, ISSN 1314-1791 (print), ISSN 2535-1214 (online).
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3. Gerdanikova, M., Stoitsov, G., Dimitrov, I. (2021) INTERDISCIPLINARY EDUCATION WITH SCRATCH IN PRIMARY SCHOOLINTERDISCIPLINARY EDUCATIONWITH SCRATCH IN PRIMARY SCHOOL, REMIA'21, University Publishing House "Paisiy Hilendarski", pp. 163-167, ISBN 978-619-202-712-4.

PARTICIPATION IN SCIENTIFIC RESEARCH PROJECTS

1. First phase of Project BG05M2OP001-2.011-0001 'Support for Success' – author of the toolkit at Plovdiv University 'Paisii Hilendarski' (2020). The Ministry of Education and Science (MES) is the specific beneficiary of the project through the direct grant procedure 'Support for Success' under the Operational Programme 'Science and Education for Smart Growth' (OPSESG) 2014-2020, co-financed by the European Union through the European Structural and Investment Funds.
2. Second phase of Project BG05M2OP001-2.011-0001 'Support for Success' – trainer at Plovdiv University 'Paisii Hilendarski' (2021). The trainings were on the topic: 'Application of the toolkit for early identification of students at risk of early leaving the educational system and for a differentiated approach in determining their needs for providing individual support'. Target group – pedagogical specialists.

ACKNOWLEDGEMENTS

I express my heartfelt gratitude to my scientific supervisor, Prof. Dr. Kosta Gurov, for the time spent and valuable advice, for the dedicated and unconditional support, for the encouragement and constructive recommendations in the development of this dissertation, for the faith and motivation, for the fruitful collaboration and the new horizons he opened up for me during my entire doctorate.

I am sincerely grateful and thankful to Senior Assistant Professor Dr. Ivan Dimitrov for the inspiration, methodological assistance, creative guidance, and dedication during my doctorate, in the development and approval of the interdisciplinary methodological model, as well as in the statistical analysis of the results.

I thank Associate Professor Dr. Gencho Stoichev for his assistance in the approval of the methodological model, as well as in the statistical processing of the results of the conducted research.

I express my gratitude to Associate Professor Dr. Stefka Aneva, Associate Professor Dr. Dobrinka Milusheva-Boykina, and Senior Assistant Professor Dr. Ivelina Velcheva for their participation in projects and forums related to my scientific research for the dissertation, as well as for creative consultations and assistance.

Last but not least, this dissertation would not have been possible without the participation of my students. I thank them for their serious attitude, active participation, and achieved results.

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