

Contemporary Technologies and Society: Innovations, Artificial Intelligence, and Challenges

Katowice
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**CONTEMPORARY TECHNOLOGIES AND SOCIETY:
INNOVATIONS, ARTIFICIAL INTELLIGENCE,
AND CHALLENGES**

Collective Scientific Monograph

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and Oleg Bogut*

Katowice 2023

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CONTENT

PREFACE	11
PART 1. INNOVATIVE EDUCATIONAL TECHNOLOGIES AND PRACTICES IN EDUCATION	12
1.1. THE CURRENT STATE OF THE IT MARKET AND HIRING CHALLENGES FOR THE IT COMPANIES (<i>Oleg Bogut</i>)	13
1.2. INNOVATIVE EDUCATIONAL TECHNOLOGIES IN THE PROFESSIONAL TRAINING OF SPECIALISTS: MODERN ASPECTS (<i>Iryna Briukhovetska, Oksana Golikova, Victoria Myroshnychenko</i>)	22
1.3. INDIVIDUALIZATION OF THE PROCESS OF PROFESSIONAL TRAINING OF FUTURE SPECIALISTS USING INNOVATIVE EDUCATIONAL TECHNOLOGIES (<i>Olha Chemerys, Volodymyr Tovstohan, Lyubov Kibenko</i>)	30
1.4. ONLINE STRATEGIES AND TOOLS FOR REMOTE TEACHING AND LEARNING IN HIGHER EDUCATIONAL INSTITUTIONS (<i>Iryna Korotiaieva</i>)	38
1.5. APPLICATION OF THE ARDUINO PLATFORM IN THE SYSTEM OF TRANSPORTATION OF THERMALLY UNSTABLE SUBSTANCES (<i>Vasyl Kot, Nazar Shynkarchuk, Valentyna Yuskovych-Zhukovska</i>)	45
1.6. DEVELOPMENT OF A SMART HOME MODULE FOR MICROCLIMATE CONTROL IN AN INTERIOR (<i>Yurii Lotiuk, Andrii Hrysiuk, Liudmyla Solovei</i>)	55
1.7. APPLICATION OF INNOVATIVE TECHNOLOGIES IN THE PROCESS OF IMPLEMENTING A NEW UKRAINIAN SCHOOL: MANAGERIAL ASPECT (<i>Tetiana Mostova, Alina Buchneva</i>)	62
1.8. IMPLEMENTATION OF MODERN INFORMATION AND COMMUNICATION TECHNOLOGIES IN THE STUDY PROCESS IN THE CONDITIONS OF DISTANCE LEARNING AND TEACHING (<i>Yuliia Nadolska, Diana Konovalenko, Anastasiia Zinchenko</i>)	69
1.9. USE OF THE LATEST TECHNOLOGIES IN VOCATIONAL TRAINING: OVERVIEW, TRENDS, CHALLENGES (<i>Vladyslava Perminova, Angela Sikaliuk, Svitlana Lytvyn</i>)	76
1.10. PROSPECTS OF SCIENCE AND EDUCATION IN THE DIGITAL ERA: EUROPEAN AND GLOBAL EXPERIENCE (<i>Mykola Popovych, Nataliia Vynnyk, Viktoriia Vorona, Mykola Iehupov</i>)	82
1.11. THE LATEST TRENDS IN ENGLISH TEACHING AS A FOREIGN LANGUAGE (<i>Viktoriia Pryma, Kateryna Borovyk</i>)	89
1.12. DEVELOPMENT OF A MOBILE APPLICATION FOR AUTONOMOUS LEARNING (<i>Oleksandr Sheremeta, Roman Sheremeta, Valentyna Yuskovych-Zhukovska</i>)	94

1.13.	THE USE OF DIGITAL EDUCATIONAL RESOURCES IN THE LEARNING OF NATURAL SCIENCE IN UKRAINIAN SCHOOL <i>(Inna Siaska, Vadym Ponomarenko)</i>	103
1.14.	PECULIARITIES OF USING TESTING E-PLATFORMS FOR ASSESSMENT OF KNOWLEDGE AND SKILLS OF DEGREE-SEEKING STUDENTS AT EDUCATIONAL INSTITUTIONS OF UKRAINE <i>(Olha Sopina, Valerii Bohdan)</i>	111
1.15.	THE ROLE OF TECHNOLOGY IN MODERN EDUCATION: TRENDS AND IMPLICATIONS <i>(Yuliia Synyshyna)</i>	118
1.16.	APPLICATION OF MULTIMEDIA TECHNOLOGIES IN THE STUDY OF DRUG ADDICTIONS AS SOCIO-POLITICAL DANGERS FOR SAFETY, LABOR PROTECTION AND CIVIL DEFENSE <i>(Andriy Tkachuk)</i>	124
1.17.	USE OF ADAPTIVE TECHNOLOGIES IN THE VOCATIONAL TRAINING SYSTEM: THEORETICAL AND PRACTICAL ASPECTS <i>(Vanda Vyshkivska, Yevhen Prokofiev, Tetiana Yelchaninova)</i>	133
1.18.	ELECTRONIC EDUCATIONAL ENVIRONMENT FOR ACQUIRING PROFESSIONAL SKILLS IN WEB DEVELOPER TRAINING <i>(Valentyna Yuskovich-Zhukovska, Oleg Bogut)</i>	140
1.19.	FEATURES OF THE FORMATION OF RESEARCH SKILLS OF SCHOOL STUDENTS WHILE WORKING ON STEM-PROJECTS <i>(Oksana Abramova, Viktoriia Vdovenko, Iryna Prykhodko)</i>	148
1.20.	INTEGRATION OF INFORMATION TECHNOLOGIES FOR EFFECTIVE TEACHING OF MEDICAL AND PHARMACEUTICAL SPECIALTIES <i>(Alina Arendarenko, Kateryna Khomenko, Chubenko Valentyna)</i>	155
1.21.	EDUCATIONAL PROGRAMS ARE A MODERN CHALLENGE <i>(Mariana Baran)</i>	161
1.22.	INNOVATIVE TECHNOLOGIES FOR TRAINING SPECIALISTS IN FOREIGN PHILOLOGY: EXPERIENCE OF HIGHER EDUCATION INSTITUTIONS OF UKRAINE <i>(Liliya Baranovska, Tetyana Tarnavska, Nataliia Zhuravel)</i>	167
1.23.	CONCEPTUAL FOUNDATIONS OF FORMING THE SOCIAL-COMMUNICATION CULTURE OF STUDENT YOUTH THROUGH THE MEANS OF LITERARY ART <i>(Olga Bilychenko)</i>	173
1.24.	ASPECTS OF USING CHATGPT AI IN BILINGUAL TEACHING OF PHYSICS IN HIGHER EDUCATION INSTITUTIONS <i>(Alla Bovtruk, Iryna Slipukhina, Sergii Mienailov)</i>	181
1.25.	THE ORGANIZATION OF PROJECT ACTIVITIES DURING THE LESSONS OF MATHEMATICS <i>(Vira Hlazova, Tetiana Kravets, Yana Pozoieva)</i>	191
1.26.	INNOVATIVE TECHNOLOGIES IN THE EDUCATIONAL SPACE – A WAY TO IMPROVE THE QUALITY OF EDUCATION <i>(Antonina Danko)</i>	198
1.27.	ON THE ISSUE OF INNOVATIVE TECHNOLOGIES IN THE EDUCATION OF PHILOLOGY STUDENTS <i>(Larisa Zhizhchenko, Nadia Tenditna)</i>	202
1.28.	THE MODEL OF THE SOCIAL AND COMMUNICATION SPACE OF A HIGHER EDUCATIONAL INSTITUTION AS A COMPONENT OF THE SOCIALIZATION TECHNOLOGY OF PHILOLOGICAL STUDENTS (ON THE EXAMPLE OF THE DONBAS STATE PEDAGOGICAL UNIVERSITY) <i>(Valentyna Kovalenko)</i>	209

1.29.	ART AS A CERTAIN SOCIO-PEDAGOGICAL SYSTEM IN THE TRAINING OF FUTURE SPECIALISTS (<i>Petro Koval</i>)	217
1.30.	DEVELOPMENT OF COGNITIVE ACTIVITY OF PRIMARY SCHOOL STUDENTS IN THE PROCESS OF IMPLEMENTATION OF THE NATURAL EDUCATIONAL FIELD (<i>Alla Kolyshkina</i>)	226
1.31.	THE INFLUENCE OF INFORMATION AND INNOVATION TECHNOLOGIES ON THE SYSTEM OF HIGHER EDUCATION IN UKRAINE DURING THE WAR (<i>Nataliia Lakusha, Lesya Chervona</i>)	234
1.32.	THE USE OF INFORMATION AND DIGITAL TECHNOLOGIES IN THE ORGANIZATION OF LABORATORY WORK IN CHEMICAL DISCIPLINES IN INSTITUTIONS OF HIGHER MEDICAL AND PHARMACEUTICAL EDUCATION (<i>Olena Masliuk</i>)	243
1.33.	FORMATION OF THE LIFE COMPETENCES OF FUTURE SPECIALISTS IN TECHNOLOGICAL EDUCATION DURING THE STUDY OF PROFESSIONAL (<i>Natalia Myronenko</i>)	249
1.34.	ROLE OF INTERNATIONALIZATION IN THE NATIONAL UNIVERSITY RANKINGS: A CASE STUDY OF POLAND AND UKRAINE (<i>Aleksander Ostenda, Yuliana Irkhina, Oleksandr Nestorenko, Tamara Makarenko</i>)	256
1.35.	TRANSFORMATION OF APPROACHES TO FINANCING INSTITUTIONS OF HIGHER EDUCATION IN UKRAINE: REGIONAL ASPECT (<i>Oksana Pysarchuk</i>)	264
1.36.	FORMATION OF PROFESSIONAL SKILLS OF FUTURE EDUCATORS OF PRESCHOOL EDUCATION INSTITUTIONS FOR THE FORMATION OF THE FOUNDATIONS OF SOCIAL AND CIVIC COMPETENCE OF YOUNG CHILDREN (<i>Tetiana Ponomarenko, Tetiana Shynkar, Larysa Harashchenko</i>)	272
1.37.	AN INTEGRAL APPROACH IN SUPPORTING EDUCATIONAL SEEKERS OF DONETSK REGION: TELETECHNOLOGIES OF ADAPTATION, RECOVERY AND DEVELOPMENT DURING THE WAR (<i>Valentyna Poul, Tetyana Kolgan</i>)	279
1.38.	THE CURRENT STATE AND PECULIARITIES OF THE FORMATION OF GENDER COMPETENCE OF APPLICANTS IN HIGHER EDUCATION INSTITUTIONS OF UKRAINE (<i>Olga Puliak, Oksana Kireieva</i>)	286
1.39.	REFLECTIVE ANALYSIS OF CONTEMPORARY CHALLENGES IN HIGHER EDUCATION (<i>Yana Suchikova, Sergii Kovachov, Tetyana Nestorenko</i>)	293
1.40.	PERSPECTIVES OF USING GIS TECHNOLOGIES IN EDUCATION (<i>Ivan Sadovyy, Mariya Grek, Anna Fedorova</i>)	304
1.41.	SOME ASPECTS OF THE DEVELOPMENT OF CREATIVE AND CRITICAL THINKING OF SCHOOLCHILDREN AND STUDENTS IN THE MODERN EDUCATIONAL PROCESS (<i>Tetjana Tarasova</i>)	311

PART 2. EMERGING TRENDS IN INNOVATION AND BUSINESS DEVELOPMENT	318
2.1. BANCASSURANCE: DETERMINANTS FOR DEVELOPMENT IN UKRAINE AND POLAND <i>(Ihor Alieksieiev, Pavlo Horyslavets, Oksana Kurylo, Andriana Mazur)</i>	319
2.2. INTRAPRENEURSHIP AS A FORM OF INNOVATION DEVELOPMENT: BASIC PRINCIPLES AND MECHANISMS OF IMPLEMENTATION <i>(Iryna Anhelko)</i>	326
2.3. THE PHENOMENON OF INNOVATIVE DEVELOPMENT AND MODERNIZATION PROCESSES OF SINGAPORE <i>(Valeria Baranova, Evgeniy Shapran, Andriy Smorodin)</i>	335
2.4. SELECTION, IMPLEMENTATION, IMPROVEMENT, AND ECONOMIC EFFICIENCY EVALUATION OF CRM SYSTEMS OF TRADE ENTERPRISES <i>(Oleksandr Bilotserkivskyi)</i>	343
2.5. HYBRIDIZATION OF RECOMMENDER SYSTEMS IN E-COMMERCE BASED ON DEMOGRAPHIC FILTERING <i>(Galyna Chornous, Yuliia Sviatiuk, Daryna Usenko)</i>	351
2.6. THE EXTERNAL ENVIRONMENT AS A DRIVER OF INNOVATIVE CHANGES AND THE SEARCH OF NEW STRATEGIC SOLUTIONS IN BUSINESS: CASE OF TERA COMPANY <i>(Oleksandr Dluhopolskyi, Taras Katola, Tetiana Dluhopolska)</i>	358
2.7. MANAGEMENT OF FINANCIAL STABILITY OF ENTERPRISES IN THE FIELD OF HOTEL SERVICES <i>(Iryna Farynovych)</i>	368
2.8. ASSESSMENT OF VOLATILITY AND THE LEVEL OF HEDGING EFFECTIVENESS ON OIL MARKETS <i>(Olha Haponenko, Maryna Mashchenko, Olena Serhiienko)</i>	376
2.9. TRANSFER PRICING OF TNCS: SUBSTANTIATION OF THE ESSENCE AND CONTENT <i>(Pavlo Horyslavets, Andrii Mukan)</i>	389
2.10. MODELING OF INNOVATION RESULTS WHEN DEVELOPING DIAGNOSTICS' MECHANISM OF ECONOMIC PROTECTABILITY OF ENTERPRISE: MATHEMATICAL AND FINANCIAL APPARATUS <i>(Iryna Khoma)</i>	396
2.11. IMPLEMENTATION OF INNOVATIVE PRODUCTS AND SERVICES – A COMPETITIVE ADVANTAGE OF THE BANK <i>(Lev Kloba, Nazar Dobosh, Orysyia Voloshyn)</i>	403
2.12. FINANCIAL AND ECONOMIC IMPLICATIONS ARISING FROM THE RUSSIAN AGGRESSION IN UKRAINE <i>(Maria Lapishko, Oksana Sadura, Zoriana Lapishko)</i>	411
2.13. "GLOOMY" TOURISM: AN INNOVATIVE DIRECTION IN UKRAINE'S TOURISM ACTIVITY IN THE FACE OF MODERN CHALLENGES <i>(Tetiana Lysiuk)</i>	418

2.14.	THE DEVELOPMENT OF DIGITALIZATION PROCESSES IN THE FINANCIAL ECOSYSTEM – THE EXPERIENCE OF UKRAINE (<i>Taras Ozarkiv</i>)	426
2.15.	UKRAINIAN IT SECTOR: TRENDS AND PROSPECTS FOR EXPORT PROMOTION (<i>Valentyna Sereda, Olena Kuzioma, Iryna Didenko</i>)	433
2.16.	INNOVATIVE DEVELOPMENT OF ENTERPRISES AND JUSTIFICATION OF THE MAIN METHODS OF ECONOMIC EFFICIENCY OF THESE ENTERPRISES (<i>Iryna Yaremchuk, Khrystyna Gorbova, Liliia Grynash</i>)	442
2.17.	HISTORICAL MILESTONES AND PROSPECTS OF INNOVATIVE TECHNOLOGY DEVELOPMENT IN AGRICULTURAL PRODUCTION (<i>Svitlana Zaika, Oleksandr Hridin, Olena Zaika</i>)	450
2.18.	TAX TOOLS AS AN INCENTIVE FOR BUSINESS INNOVATION (<i>Roman Zelizniak, Olena Pozniakova</i>)	456
2.19.	ECONOMIC ADVANTAGES OF GREEN BUILDING IN THE FIELD OF ENERGY EFFICIENCY AND ENERGY SAVING (<i>Vita Bugaychuk, Inna Grabchuk, Karyna Sych</i>)	465
2.20.	INNOVATIVE APPROACHES TO MEASURING SYSTEM RESILIENCE (<i>Vasyl Gorbachuk, Maksym Dunaievskyi, Maxim Lupey</i>)	476
2.21.	CHANGES IN CONSUMER BUYING BEHAVIOUR DURING THE WAR IN UKRAINE (<i>Iryna Yemchenko</i>)	483
2.22.	INNOVATIVE APPROACHES TO IMPROVING THE CRISIS MANAGEMENT OF BANKING INSTITUTIONS (<i>Liudmyla Zveruk, Yulia Morgun</i>)	490
2.23.	FORECASTS AND TASKS OF POST-WAR RECONSTRUCTION MIST – REGIONAL CENTERS OF UKRAINE (<i>Nataliia Lysiak, Nataliia Samotiy, Yana Pecheritsa</i>)	496
2.24.	DIGITAL TECHNOLOGIES IN THE PARADIGM OF HARMONIZATION OF THE NATIONAL ACCOUNTING SYSTEM WITH ACCOUNTING PRACTICES OF THE EUROPEAN UNION (<i>Nataliya Loboda</i>)	504
2.25.	THE STUDY OF METHODS FOR VALUATION OF INTELLECTUAL PROPERTY RIGHTS (<i>Petro Pererva, Maria Maslak, Andrii Yevsieiev</i>)	512
2.26.	USE OF INNOVATIVE TECHNOLOGIES IN PERSONNEL MANAGEMENT (<i>Olha Tkachenko</i>)	521
2.27.	THEORETICAL AND ANALYTICAL STUDY OF MARKETING ACTIVITIES OF THE BANK (<i>Leonid Tsubov, Taras Shcherban, Oresta Shcherban</i>)	528
2.28.	TYPES AND PROCEDURE OF DRAWING UP REGULATED REPORTING IN THE CONDITIONS OF MODERN INFORMATION TECHNOLOGIES (<i>Odarka Chabaniuk</i>)	534

PART 3. INTERDISCIPLINARY APPROACHES TO RESILIENCE, INFORMATION IMPACT, AND ENVIRONMENTAL ASSESSMENT IN THE CONTEXT OF SOCIETAL CHALLENGES	543
3.1. PSYCHOLOGICAL FEATURES OF THE DEVELOPMENT OF RESILIENCE IN INTERNALLY DISPLACED PERSONS AS A RESOURCE FOR OVERCOMING THE TRAUMA OF WAR <i>(Iryna Bulakh, Valentina Voloshyna, Hanna Varina)</i>	544
3.2. INFORMATION AND PSYCHOLOGICAL IMPACT ON SOCIETY IN THE CONTEXT OF WAR IN UKRAINE <i>(Olga Kovalova, Ella Eminova)</i>	553
3.3. ECOLOGICAL SAFETY ASSESSMENT SYSTEM OF THE RIVERS IN LVIV REGION BASED ON FUZZY LOGIC MODEL <i>(Yuliia Kurylchuk, Marta Mashevskia)</i>	560
3.4. USING THE INFORMATION TECHNOLOGIES FOR QUALITY MONITORING OF DIFFERENT ENVIRONMENTAL IMPACTS ON HUMANITY LIFE <i>(Andrii Lagun, Nataliia Kukharska)</i>	574
3.5. PROFESSIONAL DEFORMATIONS AND FRUSTRATION OF TEACHERS AS A SOCIAL PROBLEM <i>(Iryna Ostopolets, Olesia Prokofieva, Liliia Kobylnik)</i>	582
3.6. IMPLEMENTATION OF COACHING TECHNOLOGIES IN THE PRACTICE OF PSYCHOLOGICAL COUNSELING <i>(Hanna Varina, Svitlana Shevchenko)</i>	588
3.7. THEORETICAL ANALYSIS OF THE INFLUENCE OF VOLUNTARY REGULATION ON THE PROFESSIONAL ADAPTATION OF EMPLOYEES OF THE STATE EMERGENCY SERVICE OF UKRAINE <i>(Nataliia Svitlychna, Vasyl Matukhno, Mykhailo Dolhodush)</i>	597
3.8. INNOVATION IS THE WAY OF DEVELOPMENT AND ITS STRATEGIC SIGNIFICANCE FOR SOCIETY <i>(Alexander Sklyarenko)</i>	602
3.9. MATHEMATICAL MODELLING OF THE ASSESSMENT OF TERRITORIES STATE FOR THE NATURE RESERVE FUND OF NATIONAL SIGNIFICANCE <i>(Lesia Uhryn)</i>	607
PART 4. ARTIFICIAL INTELLIGENCE IN EDUCATION, HEALTHCARE, AND SOCIETY: OPPORTUNITIES AND CHALLENGES	613
4.1. ARTIFICIAL INTELLIGENCE – FRIEND OR FOE FOR UKRAINIAN STUDENTS <i>(Ilona Boichevska)</i>	614
4.2. RECOMMENDATION SYSTEM FOR MOVIE SELECTION USING ARTIFICIAL INTELLIGENCE <i>(Ievgen Sidenko, Oleksandr Malimon)</i>	620

4.3.	OPPORTUNITIES AND THREATS OF ARTIFICIAL INTELLIGENCE DEVELOPMENT IN CITIES <i>(Tetiana Tkachenko, Oleksandr Hladkyi, Valentyna Zhuchenko)</i>	628
4.4.	FEATURES AND PROSPECTS OF AUTOMATION OF COMPLEX DYNAMIC PROCESSES BASED ON MODERN INTELLIGENT CONTROL AND DECISION SUPPORT SYSTEMS <i>(Yue Zheng, Oleksiy Kozlov, Chenjian Dong)</i>	633
4.5.	THE USE OF ARTIFICIAL INTELLIGENCE IN EDUCATION AS AN EFFECTIVE TOOL FOR DEVELOPING FOREIGN LANGUAGE COMMUNICATIVE COMPETENCY <i>(Iryna Shvetsova)</i>	642
4.6.	ARTIFICIAL INTELLIGENCE AND NEURO-TRAINING FOR CHILDREN WITH DEVELOPMENTAL DIFFICULTIES. WHEN TECHNOLOGY HELPS <i>(Olha Kovalova, Tetiana Martynova-Hanetska)</i>	648
4.7.	ADVANTAGES AND DANGERS OF ARTIFICIAL INTELLIGENCE IN MEDICINE <i>(Jevgenija Nevedomsjka)</i>	655
PART 5. ADVANCEMENTS IN PHYSICAL EDUCATION AND REHABILITATION: THEORY AND PRACTICE		663
5.1.	TEACHING 7-8-YEAR-OLDS BREATHING TECHNIQUES WHILE SWIMMING FRONT CRAWL <i>(Karen Abramov, Oksana Petrenko)</i>	664
5.2.	MEDICAL REHABILITATION IN PODILLIA (UKRAINE): EXPERIENCE OF CREATION AND PROSPECTS OF DEVELOPMENT <i>(Volodymyr Kylyvnyk, Oleksandr Hladkyi, Yaroslav Luchenko)</i>	668
5.3.	MODERN APPROACHES TO THE PREVENTION OF SPORTS INJURIES <i>(Viktorii Babalich)</i>	675
5.4.	METHODOLOGICAL SUPPORT FOR THE IMPLEMENTATION OF THE INTEGRATED TECHNOLOGY FOR THE FORMATION OF HEALTH-SAVING COMPETENCE OF PRIMARY SCHOOL CHILDREN IN THE PROCESS OF PHYSICAL EDUCATION <i>(Alona Vitchenko, Liudmyla Lysenko)</i>	681
5.5.	ASSESSMENT OF TEENAGERS' PHYSICAL HEALTH INDICATORS IN TERMS OF DISTANCE LEARNING <i>(Olena Dmytrotsa, Olha Korzhyk, Victoria Demchuk)</i>	691
5.6.	IMPACT OF ADDITIVES OF 12.5 wt% MICRO-NANO-PARTICLES OF METALS (Cu, Fe, Al) ON THE POWER OF EPOXY COMPOSITES for SPORTS and REHABILITATION MATERIALS <i>(Yaroslav Krenevych, Dmytro Starokadomsky, Mariia Reshetnyk, Nataliia Bodul)</i>	698
5.7.	THEORETICAL ASPECTS OF TEACHING STUDENTS TO PROVIDE HOME MEDICAL AID AT LESSONS ON DEFENSE OF UKRAINE <i>(Olena Nievorova, Valentyna Cherniy)</i>	708

5.8.	IMPLEMENTATION OF THE NEWEST TECHNOLOGIES IN REHABILITATION <i>(Oksana Polianska, Igor Polianskyi, Olha Hulaha, Inna Moskaliuk)</i>	715
5.9.	PECULIARITIES OF THE DEVELOPMENT OF GNUCHKOST AND METHODS OF Ї THOROUGHLY AMONG STUDENTS IN THE LESSONS OF SPORTS GYMNASTICS <i>(Iryna Sundukova, Oleksiy Stasenko)</i>	721
5.10.	DEVELOPMENT OF COORDINATION OF MOVEMENTS IN SPORTS- PEDAGOGICAL IMPROVEMENT CLASSES IN ARTISTIC GYMNASTICS <i>(Olga Shevchenko, Anastasia Melnik)</i>	728
5.11.	MODERN TECHNOLOGIES OF PHYSICAL CULTURE AS A COMPONENT OF THE EDUCATIONAL PROCESS OF GENERAL SECONDARY EDUCATION IN UKRAINE <i>(Oksana Yazlovetska, Nataliia Shcherbatiuk, Serhiy Sobko)</i>	735
	ANNOTATIONS	743
	INFORMATION ABOUT AUTHORS	772

2.17. HISTORICAL MILESTONES AND PROSPECTS OF INNOVATIVE TECHNOLOGY DEVELOPMENT IN AGRICULTURAL PRODUCTION

In the current conditions, the emergence of problems in the agricultural production sphere is attributed to wartime actions, which in turn caused economic destabilization and reduced financial resources within the country. These issues during the post-war country reconstruction can be addressed through the implementation of innovations, which should become the primary direction of agricultural sector development. The absence of innovative processes leads to the inability to effect structural changes, dynamic economic growth, and attain sustainable development within the economy (Mandych et al., 2023). Innovations play a crucial strategic role in the effective transformation and advancement of agriculture. They contribute to stimulating agricultural entrepreneurship, enhancing competitiveness in domestic and international markets. This is especially important in the context of a market-oriented economic system and increased integration into the global agro-industrial production (Zaika et al., 2023; Заїка, Грідін, 2016). This is particularly relevant due to the significant technological gap between Ukraine's agricultural sector and leading global agricultural product manufacturers.

Hence, to achieve effective and sustainable development of agricultural production, which holds pivotal strategic importance for ensuring national food security, active support for innovation implementation and the establishment of proper infrastructure for this process are necessary. This requires scientific research that will facilitate the successful integration of innovative solutions into agricultural production.

Research on issues related to the innovative development of agricultural production remains a constant focus for many scholars. Their works provide a substantial foundation for studying the problems of innovative development in agriculture. However, the complexity and scale of these processes allow for the discovery of inadequately researched aspects of this issue and the continuation of scholarly efforts. This study is aimed at identifying the prospects of innovative development in agricultural production to enhance its efficiency.

Technological progress in agriculture is closely linked to the growth of commercial trade. In this field, new technological developments have always been necessary. However, digital technologies in agriculture did not emerge immediately. In the early stages of technological development, the agricultural production model was largely based on subsistence farming and characterized by low productivity until the beginning of the 20th century. This era, known as Agriculture 1.0, was marked by the invention of the plow and the widespread use of animal traction.

Agriculture 2.0 emerged in the late 19th century with the introduction of mechanized equipment, such as tractors. Subsequently, new agricultural technologies underwent several rapid stages of development, as the pace of technical progress significantly increased.

New technologies of precision or smart farming, known as Agriculture 3.0, arose due to the need to track and manage all agricultural production resources more efficiently (Мазнєв, 2008; Мазнєв, 2015). The drive for precision agriculture and the adoption of corresponding technologies led to the development of new methods and tools for farming. The 3.0 era became technically feasible through the use of a new global positioning satellite system (GPS). Specifically, the GPS helps identify unwanted changes in designated agricultural cultivation areas, enabling the efficient utilization of available resources. The concept of sustainable agriculture and research in the field of automated field processing heavily rely on GPS technologies and the new capabilities it provides.

The transition from smart farming to Agriculture 4.0 demonstrates the rapid development of

agriculture at the turn of the 20th and 21st centuries. Autonomous machines equipped with sensors, augmented reality (AR), Internet of Things (IoT), drones, and satellites are integral components of the new technologies for Agriculture 4.0. A new approach to decision-making in the agricultural sector is currently based on data stored in the cloud and accessible through digital tools. Leveraging these analytical data, agricultural producers can make more effective decisions.

Agriculture 4.0 was born in the era of automation and the use of digital technologies. The development of innovative agricultural technologies is becoming increasingly integrated, allowing for the optimization of all stages of the production process and enhancing monitoring, control, and business management processes.

Digital agricultural technologies represent the next generation of new farming methods and tools aimed at maximizing crop yield and other agrotechnical indicators. One of these innovative technologies is 5G mobile communication, which is rapidly advancing and will improve the coverage and accessibility of cutting-edge agricultural technologies worldwide (Botta et al., 2022; Duncan et al., 2022). Compared to previous farming methods, innovative digital technologies in agriculture offer the following advantages (Hridin et al, 2023):

- Efficient data collection;
- Data accuracy;
- Timeliness.

Agricultural producers cannot influence weather conditions, and combating pests and plant diseases is quite challenging. However, with the emergence of innovative digital technologies in agriculture, the negative impact of these factors can be minimized. Moreover, through the use of new agricultural technologies, farmers can control agrotechnical aspects and, consequently, increase their profits. In particular, digital technologies in agriculture help provide informed answers to questions such as (Thapa & Horanont, 2022; Zhou et al., 2023):

- Which types of crops to cultivate;
- Which types of crops to cultivate;
- How frequently and in what quantity to use water for precise irrigation;
- When to apply fertilizers and plant protection agents, which ones, and in what amounts;
- Which type of soil treatment is best suited for a given soil type.

Competitive advantages of agricultural enterprises are ensured through the utilization of modern software, Earth remote sensing technologies (especially high-resolution satellite imagery), proximal sensors, new communication tools, and data-driven risk prediction algorithms.

In recent years, the agricultural sector has achieved several crucial advancements, from enhancing seed resilience to refining the planning and processing of agricultural products. Innovative agricultural technologies also contribute to optimizing the planning of agricultural product sales and improving logistical decisions related to its delivery to end consumers.

To achieve maximum yield improvement and keep pace with the times, agricultural producers must be well-versed in technological innovations and be aware of their potential applications in agricultural production. Let's delve more deeply into the main ones.

GPS. New precision farming technologies utilizing GPS data contribute to increased productivity and reduced irrational expenditures on production resources such as seeds, fertilizers, pesticides, and fuel. The GPS system not only provides field information based on location but also simplifies coordination among individual agricultural machinery units and facilitates recording of field operations on specialized platforms. This new technology finds diverse applications in the agricultural sector, such as monitoring and managing field operations, collecting and analyzing field data, precise soil sampling for analysis, yield mapping, navigation and control of new agricultural equipment, functioning in conditions of poor visibility, like heavy rain or fog, etc.

Robotic technologies. Robotic technologies in agriculture are a promising avenue for new labor force in precision farming. The autonomous operation of robotic systems allows for increased productivity and efficiency in agriculture, as these robots can gather information about their surroundings directly on the field. Currently, autonomous robots that are remotely controlled through telemetry are the most well-known and successfully utilized form of new agricultural equipment.

Data collection and storage. The utilization of Big data in innovative agricultural technologies contributes to intensifying information flows, enhancing the speed and accuracy of analysis, and consequently, improving the efficiency of decision-making processes and strategic planning. Retrospective analysis of field data enables the prediction of potential outcomes of various phenomena and factors, assessment of risks, and the development of optimal action plans.

Information technologies in agriculture are continuously evolving, and specialized platforms can collect and store increasing amounts of field data, such as relative humidity, nutrient content, pH, and soil moisture, as well as historical weather data, and more. Based on data presented in a simple and accessible format, platform users can identify risks, plan cultivation, and forecast future yields.

GIS technologies. Geographic Information Systems (GIS) are a novel and essential tool for storing, analyzing, and visualizing spatial data for the needs of precision agriculture. One of the most crucial aspects of applying GIS technologies in agriculture is gathering information about agricultural crops, soil, climate, and the topography of the region using satellites and drones. Moreover, it is through these new GIS technologies applied in agriculture that the combined use of GPS applications and smart farming tools becomes possible for the optimal distribution of fertilizers and pesticides. Thus, these new technologies in agriculture not only help reduce financial costs for fertilizer purchases but also prevent soil and groundwater pollution due to improper chemical usage.

In recent years, thanks to the development of innovative technologies, the number of applications for utilizing GIS in agriculture has significantly grown. The main directions of these systems' application are precision farming and mapping. For instance, GIS software enables the creation of detailed maps of vegetation and productivity, which assists in decision-making optimization. Through GIS tools for agriculture, the level of vegetation across the entire field or a specific area can be determined. This information is then used for adjusting seed planting rates, nutrient application, and pesticide use.

Furthermore, the use of GIS in agriculture greatly facilitates the analysis of soil and crop conditions. Specifically, it is possible to create maps of productivity and vegetation based on vegetation indices. Moreover, mapping helps optimize field monitoring and production management as a whole.

GIS technologies for agriculture are actively utilized in the development of organic farming. With their assistance, one can identify the most productive and environmentally friendly areas for crop planting and select suitable lands for seamless food production in the future. Today, organizations engaged in sustainable development issues use GIS in agriculture to:

- control water supply and predict droughts;
- assess crop yield;
- analyze economic and ecological consequences of natural disasters and human activities;
- integrate and study agricultural data from multiple sources;
- exchange information and maps with internal departments and external organizations.

Contributing to the development of sustainable agriculture, geographic information systems help the agricultural sector remain viable for future generations.

Drones. Unmanned Aerial Vehicles (UAVs), or drones, are finding increasing applications in the agricultural sector. They can scan fields from above and report on the presence of pests, plant diseases, and deficiencies in essential nutrients. Based on this data, agricultural producers can monitor the condition of their fields.

Satellite Technologies. The use of satellites for agricultural purposes has been a true breakthrough in field monitoring, as it has led to a significant increase in data volume and collection frequency. Satellite sensors track, measure, and record electromagnetic radiation for subsequent data analysis.

Through innovative satellite technologies in agriculture, particularly with up-to-date and retrospective satellite imagery, the development of crops can be tracked throughout the entire season, even in large-scale and hard-to-reach areas. This information can serve various purposes, including assessing the effectiveness of agricultural cultivation techniques.

Therefore, in the era of informational advancements, new technologies are finding increasing applications in the agricultural sector. Agricultural enterprises employ innovative technologies to optimize field management, and this is just one of many examples of how innovation contributes to progress in agriculture.

Currently, the agricultural sector and the IT industry in Ukraine exhibit significant potential. IT companies are emerging, focusing their activities on the agricultural sector and investing their resources in developing innovative solutions for agricultural production. Among such companies are "Bvblogic," which has over 10 years of experience in developing software for agribusiness, and "AgTech Ukraine," which focuses on key tasks related to (Шебаніна, Кормишкін, 2019):

- by shaping and consolidating the AgTech Ukraine market development;
- through the creation of a platform for information exchange and interaction between the IT and agricultural sectors;
- by informing farmers about the opportunities of existing and new agricultural technologies and the results of their mutually beneficial integration;
- by informing IT companies about the needs of the agricultural sector and the specifics of implementing integrated technological solutions and their components in agricultural production;
- through the development and creation of new products;
- by providing consultation and service support.

AgTech Ukraine offers innovative solutions for the development of agricultural production in the following areas:

- agricultural biotechnology, including advanced approaches to crop cultivation and animal production, such as soil research, genetics, breeding, and animal health;
- farm management software, sensors, and Internet of Things (IoT) solutions, encompassing data collection from various devices, decision support software, and analytics;
- agricultural robotics, mechanization, and equipment;
- bioenergy and biomaterials;
- new agricultural systems, including indoor farming, aquaculture, insect breeding, algae, and microbial cultivation;
- agricultural marketplaces – trading platforms for goods, online purchasing, and equipment leasing;
- intermediate control technologies ensuring food safety, process traceability, logistics, and transportation, while also extending product shelf life.

These innovative solutions aim to enhance the efficiency and sustainability of the agricultural sector, contributing to the country's food security.

Currently, breeders, biologists, technologists, and other experts, as well as IT specialists, are actively engaged in the search for and development of innovative solutions that have significantly transformed the conditions and effectiveness of many economic entities in recent years. Thanks to the contributions of IT specialists, companies, and experts in information technology, many industries now have access to innovative and improved tools and technologies that enhance work efficiency and

support sustainable development. Scientists (Шебаніна, Кормишкін, 2019) identify eight key directions of IT innovations in the agricultural sector (Table 1).

Table 1. Directions of IT innovations in agricultural production

<i>Directions</i>	<i>Advantages of application</i>
1. Cartography	The application of modern electronic cartographic solutions helps address most typical challenges of agribusiness companies. Through cartographic solutions, soil analysis, satellite imagery, crop yield mapping, identification of productive areas, monitoring crop development dynamics, and yield forecasting can be carried out.
2. Logistics solutions	Efficient logistical IT solutions aimed at optimizing collection and delivery routes of finished products from producers to warehouses or other facilities. Implementation of automated logistical solutions in the practical operations of agricultural enterprises enables substantial savings in delivery time, fuel costs, improved product harvesting processes, reduced risk of spoilage, and significant reduction of unproductive costs in agricultural production.
3. Equipment monitoring	The incorporation of equipment monitoring (using GPS tracking) allows agricultural producers to optimize planning of both major and routine repairs, preemptively identify wear on specific parts or machinery components through data tracking and notification systems. Moreover, it offers the capability to construct machinery usage schedules, ensure safe operation, and promptly transmit data about land and crop conditions to the company's headquarters.
4. Planning and analytics	Analytical systems address issues concerning optimal plant rotation and arrangement, facilitate seed sowing and harvest processes, minimize dependence on climatic conditions, automate irrigation, fertilizer, and pesticide application systems, and more.
5. CRM and HRM systems	The use of specialized systems simplifies the management of relationships with clients, partners, and company personnel. This includes personalized interactions with each client, subsequently leading to increased sales and competitive positioning in the market. Additionally, real-time instructions can be provided to employees, inquiries can be addressed, and employee performance evaluated through online platforms.
6. Analytics and making rational decisions	Modern analytical systems enable automatic calculation of seed, pesticide, and fertilizer requirements while managing the agribusiness budget effectively based on efficiency principles.
7. Monitoring in animal husbandry	Contemporary information monitoring systems offer capabilities such as: automated herd structure planning, veterinary measures, formation of feeding regimes, and maintaining optimal microclimates on farms.
8. Mobility	The utilization of smartphones and mobile applications enables monitoring and control of transportation, drivers, reminders, warnings, support, and guidance. Mobile applications provide around-the-clock access to necessary information, allowing instant data input and distribution among employees.

The using of innovative technologies in agricultural enterprises enables the effective management of large datasets, conducting analyses of obtained results, and making informed decisions. These decisions contribute to cost minimization, profit maximization, and increased competitiveness in agricultural production. Establishing an information support system for agricultural enterprises based on modern computer and mobile technologies stands as a strategic goal for the further development of agricultural production. Its main directions include the computerization of agricultural enterprises, training and upskilling of personnel engaged in agricultural production, creating a systemic foundation, and eventually forming a unified information space.

Thus, the integration of innovations into the agricultural sector can lead to significant economic,

social, and environmental benefits. The discussed innovative technologies influence the development of agricultural production and the operations of agricultural enterprises, substantially enhancing the efficiency of agri-food systems by affecting the value creation sequence within agricultural production.

Agrarian producers play a pivotal role in this process, gaining new cooperation and innovation opportunities through contemporary technologies. Research indicates that essential indicators facilitating the effective implementation of innovative technologies in agriculture include the initiative and interest of agrarian producers combined with a desire to enhance productivity and profitability. Given access to necessary resources and favorable conditions for transforming agricultural production, agricultural enterprises can establish strategic partnerships on innovative foundations, access crucial support, employ innovative technologies both in the field and in management, explore new markets, and acquire new clients. This collective effort will result in a significantly elevated level of productivity during the innovative transformations of the agricultural sector.

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