

UDC: [378.147:62]:004

Vladimir S. Morkun

D.Sc., Prof.

Bayreuth University, Bayreuth, Germany

ORCID ID 0000-0003-1506-9759

*morkunv@gmail.com***Serhiy O. Semerikov**

D.Sc., Prof.

Kryvyi Rih State Pedagogical University, Kryvyi Rih, Ukraine

ORCID ID 0000-0003-0789-0272

*semerikov@gmail.com***Svitlana M. Hryshchenko**

PhD (Pedagogy)

Senior Researcher, Associate Professor

State Tax University, Irpin, Kyiv, Ukraine

ORCID ID 0000-0003-4957-0904

s-grischenko@ukr.net

GEOINFORMATION TECHNOLOGIES IN THE TRAINING OF FUTURE MINING ENGINEERS

Abstract. Modern world cannot live without digital technologies. Digital technologies have reached an unprecedented flourishing. The constant growth of information has led to the emergence of many opportunities for digital transactions in various professions, one of which is the mining engineer. The process of reforming this profession requires more efficient use of digital technologies in the environment, ensuring information management through the introduction of innovations, creation of databases, programs, the implementation of which will improve the quality of management of innovation processes. One of the promising directions of solving this problem is the use of geoinformation technologies. Ukraine's interest in increasing the number of engineers is manifested, in particular, in measures to encourage applicants to enter higher education institutions for engineering specialties by providing additional benefits. In the professional activities of mining engineers, information technologies make it possible not only to consider the location of production units of a mining company, mineral warehouses and rock dumps of a mining company at any required level of detail, but also to help meet the basic environmental requirements in the field of mining. The program of experimental research to test the effectiveness of methods of using Geoinformation technologies in the formation of environmental competence was implemented in three stages: analytical and stating, design and search and forming and generalizing. The discrepancies identified at the analytical and stating stage of the pedagogical experiment required the development of a new competence system with separate components of environmental competence. Multifunctional geographic information systems were used in the laboratory classes of the control groups, and multifunctional GIS, mining and environmental GIS and the software component of the methodological complex "EcoKryvbas" were used in the experimental ones. Upon completion of the experimental training, it was found that 49.33% of the students in the control groups reached an average level of environmental competence, 20% reached a sufficient level, while in the experimental groups 37.33% of the students reached a sufficient level and 36% reached an average level. In the continuation of scientific research of this problem, it is advisable to develop a methodological system of teaching Geoinformation technologies for students of specialty 122 "Computer Science".

Keywords: geoinformation technologies; pedagogical experiment; digital technologies; mining engineer.

1. INTRODUCTION

Digital technologies help us to realize our ambitions and achieve our goals. Innovation is constantly ongoing in the digital space. Many engineering and scientific problems require solving. The scale of work on assessing the impact of mining on the environment, taking into account the specifics of natural and climatic conditions, led to the choice of geoinformation technologies - a set of methods, tools and techniques used to collect, systematize, store, process, transmit, and present spatially coordinated messages and data. The use of geoinformation technologies in the professional activity of a mining engineer ensures the fulfillment of the basic environmental requirements in the field of mining through geomodeling of the location of production units of a mining enterprise, remote monitoring of the use of environmentally friendly mining technologies on the Earth's surface, systematic analysis of multilevel and heterogeneous geoinformation in the process of introducing advanced technologies for open-pit mining, aerospace sensing, and the use of environmental geoinformation technologies is the basis for optimal management of a mining enterprise, as well as forecasting and monitoring of the environment, which leads to rational economically and environmentally balanced development of natural resources in mining areas. In this regard, the social significance of teaching geoinformation technologies to future mining engineers reflects a component of the concept of sustainable development - sustainable environmental development. Geoinformation technologies can mark the location of mining enterprise facilities, mineral fistulas and dumps with any necessary detail; provide the monitoring of wastewater and air purification during the introduction of progressive mining methods; model sanitary protection zones between the mining enterprise and residential buildings in accordance with the legislation; provide a set of measures to prevent sedimentation, immersion, salinization, drainage, and surface pollution by industrial waste; prevent the adverse impact of drainage on the level of grounded waters and surface water bodies; monitor the reduction of emissions of pollutants in the mining industry and the implementation of measures to prevent emergency situations related to the to the emissions, etc.

The problem statement. For Ukraine, digital education in the training of a mining engineer is extremely relevant in the context of its economic, social, and cultural development, as stated in the Strategy for the Development of Higher Education in Ukraine for 2022-2032 [1].

The use of digital technologies in education, namely in the training of a mining engineer, contributes to:

- Increasing motivation, interest in educational activities and methods of acquiring knowledge;
- Individualization and differentiation of education through the individual pace of learning and methods of providing educational material;
- More active involvement of students in intensive, creative educational work, independent acquisition of knowledge, mastery of modern methods of scientific knowledge;
- Increasing the efficiency of independent work.

Modern training technologies at higher engineer training institutions are to be directed at training a specialist characterized by high professional competence and professional mobility, ready for lifelong learning.

Currently, especially topical is ICT application in teaching profession-oriented courses for engineering students. Training of future engineers possessing a constructive research approach to performing professional duties, able to design engineering projects independently

and provide high-level management becomes an urgent necessity. It enables us to define the following approaches to training engineering students:

- Forming students' motivation and stimulating their cognitive activity in the training process;
- Professional orientation of the training process;
- A lecturer's creative approach to organizing the training process and forming students' creative attitude towards learning in the subject-oriented electronic environment;
- A complex application of interactive methods and means in the training process;
- A systemic control and assessment of the quality of a future engineer's training throughout the whole period of training.

The scientific novelty of this research lies in the clarification of the concept of "geographic information ICT" as a set of methods, tools and techniques used to collect, systematize, store, process, transmit and present spatially coordinated messages and data.

Analysis of recent studies and publications. The basic regulatory document determining legal and organizational grounds of mining engineers' activity, including mining operations, accident prevention at mining enterprises, establishments and organizations is the Mining law of Ukraine [2]. The law regulates mining, preparation and extraction, running of mining enterprises, accident prevention and safety during mining operations, especially environmental safety, specific working conditions in the mining industry, closure of mining enterprises, etc.

Various aspects of professional training of mining engineers were investigated by O. V. Derevyanko [3], S. O. Zelinska [4], Morkun V.S. [5-7] and other scientists.

An analysis of the recent studies and publications on the investigated issues reveals that the use of modern geoinformation technologies was investigated by S. O. Semerikov, S.M. Hryshchenko., V.S. Morkun [5-7] and other scientists.

The influence of information technologies on the educational process was featured in the works of R.V. Ilchenko [8], K.R. Kolos [9], V.Y. Bykov [10], M.I. Zhaldak [11], V.Y. Bykov, O. V. Ovcharuk, I. V. Ivaniuk, O. P. Pinchuk, V. O. Halpierina [12], O. P. Pinchuk, S. G. Lytvynova, O. Y. Burov [13], O. M. Spirin, Y. H. Nosenko, A.V. Iatsyshyn [14], O. M. Spirin, S. M. Ivanova, A. V. Yatsyshyn, L. A. Luparenko, A. F. Dudko & A. V. Kilchenko [15], V. Y. Bykov, O. M. Spirin, Y. S. Ramskyi, V. M. Franchuk, N. P. Franchuk & A. V. Iatsyshyn [16] and others.

The formation of a specialist's environmental competence has been the subject of research at different levels: general education in environmental culture and consciousness (Michael K. Stone) [17]; general professional levels in environmental awareness (Zenobia Barlow) [18], David W. Orr. [19], formation of environmental competence (Carmel Bofinger) [20], B. E. Harvey [21]. Thus, a complex solution is called for in order to solve the problem of environmental competence; this needs to involve a means to determine its content, structure, and position in the system of professional competences, levels, criteria, and formation indicators.

The purpose of the study is to theoretically substantiate and experimentally test the methodology of using geographic information technologies as a means of forming the environmental competence of future mining engineers.

Fig. 1. reveals the contribution of the state policy principles in mining to social, economic, environmental and technological development of the society, which Abdallah M. Hasna [22] considers as the function of sustainable development, the model of resource usage aimed at satisfying human needs and preserving the environment in such a way that these needs could be satisfied not only by the present-day generation but also by the next ones. Thus, the state policy in the mining industry targets for sustainable development of the mining

industry, science and education. The annual international scientific and technological conference “Sustainable development of industry and society” held by Kryvyi Rih National University since 2004 provides the theoretical background for this activity.

Notwithstanding the artificial equality of the component planes of the society’s development (Fig. 1), they are not commensurable. The report of 1987 by the World commission on the environment and development “Our Mutual Future” [23] indicates the environment development (environment protection, sustainable usage of non-renewable resources, etc.) among other issues of sustainable development (population and human resources, food safety, species and ecosystems, energy, industry and urban development) as system-forming.

Basic environmental requirements for conducting mining operations, preventing their harmful effects and ensuring environmental safety are not only considered in separate articles of the Mining Law of Ukraine, but are also compulsory components of environmentally competent mining engineers’ professional training according to the standards mentioned above.

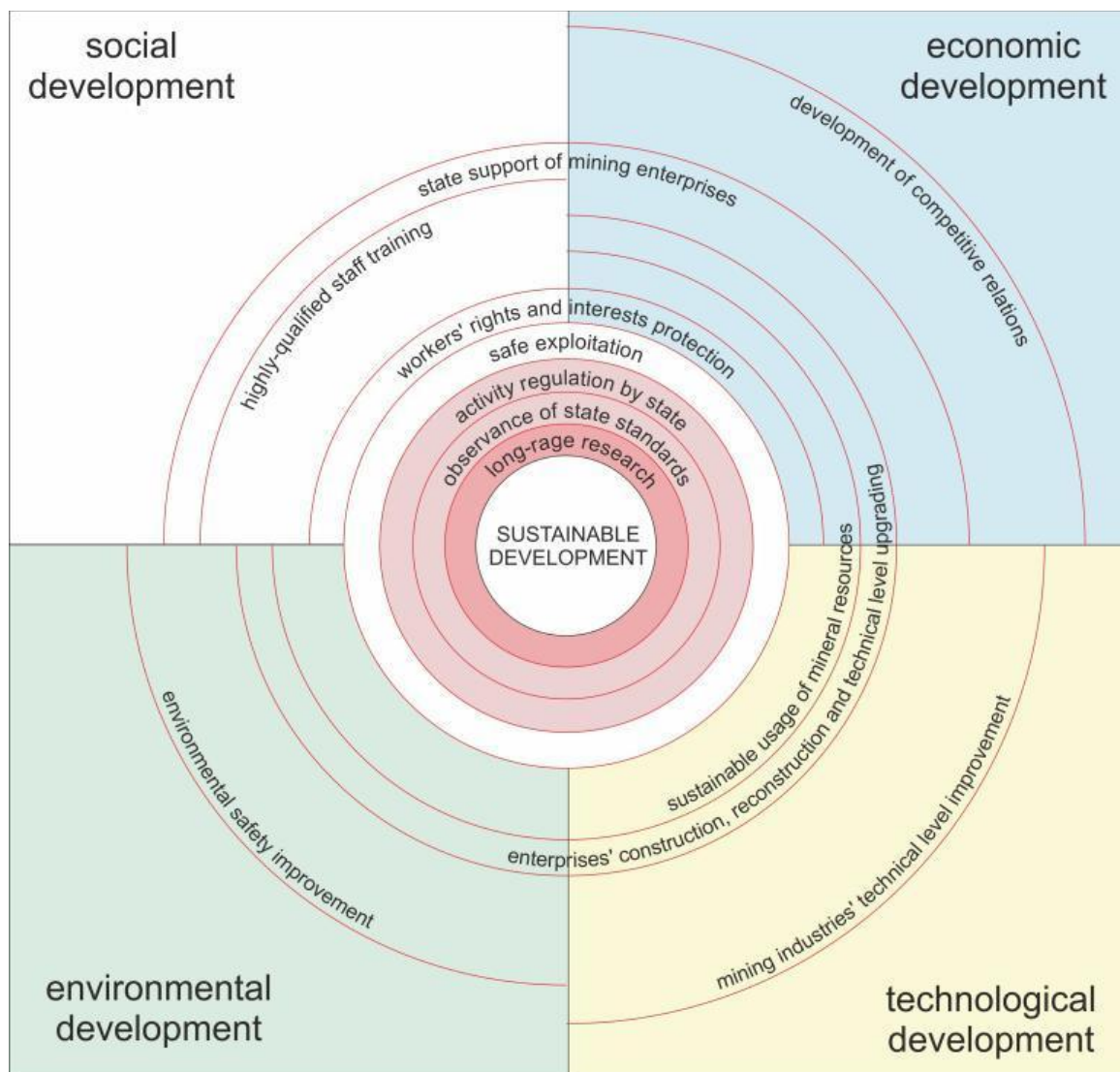


Fig.1. Reflection of state policy principles in mining on components in society's sustainable development

profession-oriented environmental knowledge (a cognitive criterion), mastered methods of providing environmentally safe mining operations (a praxiological criterion) aimed at sustainable environmental development (an axiological criterion) and formed qualities of a socially responsible environmental behaviour (a social-behavioural criterion). It comprises the following components: 1) understanding and perception of the ethical standards of behaviour in relation to other people and nature (the principle of bioethics); 2) environmental literacy; 3) knowledge of basic information on ecology to be used in one's professional activity; 4) the ability to use scientific regularities and methods while assessing the environmental condition, take part in environment-saving operations, conduct an environmental analysis of measures in the field of activity, develop the plans of measures aimed at decreasing the technogenic pressure of industrial production on the environment; 5) the ability to ensure the environmentally balanced activity; mastering the methods of sustainable and complex use of the georesource mineral potential.

The formation of future mining engineers' environmental competence provides, in particular, for the mastering of the methods ensuring the environmentally safe activity aimed at sustainable and complex use of the georesource mineral potential. It requires the complex application of methods of natural sciences: physics, chemistry, biology and ecology, on the one hand, and geology, geography and hydrometeorology, on the other hand. The designed content of the environmental competence components in future mining engineer training (2.3) implies the pronominal application of the first group of natural sciences (sciences about the transformation of substance and energy in animate and inanimate nature) to form the second and the third component as well as the second group (Earth sciences) to form the fourth and the fifth component of the environmental competence. Part of the problem of applying ICT in future mining engineers' professional training is solving the task of applying geographical ICT means.

The ICT application to investigating Geosystems has caused the appearance of *Geoinformatics*, a field of science and technology that reflects and investigates natural and socio-economic geosystems, their interaction and development by means of computer simulation (modeling) on the basis of information systems and technologies, knowledge and databases [27].

Geoinformatics is aimed at investigating general properties of geographical information (Geoinformation), regularities and methods of data obtaining, fixation, accumulation, processing and application, as well as the development of theory, methodology and technologies of creating Geoinformation systems (GIS) aimed at space-coordinated data collection, systematization, storage, processing, transformation and presentation.

The functions of GIS include the analysis of geographical (space-related) data, their visualization in the form of maps and schemes. The GIS appeared at the crossroads of data processing technologies used in database management systems (DBMS) and visualization of graphic data in systems of computer-aided design and graphics.

The significance of scientific and technical problems of Geoinformatics for the country's economy consists in providing information, control and support for making managerial decisions in planning, designing and conducting research in Earth sciences and related socio-economic sciences, developing education and culture, preserving environmental balance, preventing accidents and enhancing the country's defense potential.

As a science, *Geoinformatics* investigates the following:

- Theoretical and experimental investigations in the field of developing scientific and methodological foundations of geoinformatics;
- Technical means of geoinformation collection, registration, storage, transmission and processing using computing machinery;

- GIS of various purposes, types (referential, analytical, expert, etc.), space coverage and subject content;
- Digital databases and banks for various subject fields as well as DBMS;
- Knowledge bases on different subject fields;
- Mathematical methods, information, linguistic and software support of GIS;
- Computerized geoimages of new kinds and types; animated, multimedia, virtual and other electronic products;
- Geoinformation infrastructures, methods and technologies for storing and applying geoinformation on the basis of knowledge and databases;
- Telecommunication systems of space-time geoinformation;
- Interrelation of Geoinformatics, cartography and aerospace sounding.

Geoinformatics uses the means of information-communication technologies – a set of methods, means and techniques used for collecting, systematizing, storing, processing, transmitting and presenting various messages and data [11, p. 8] – for processing specific (space-coordinated) data. Thus, we interpret **geoinformation information-communication technologies (geoinformation ICT, geoinformation technologies)** as *a set of methods, means and techniques used for collecting, systematizing, storing, processing, transmitting and presenting space-coordinated messages and data*.

The introduction of time dimension of data is one of the manifestations of a multidimensional character of space data and of multidimensional, in particular four-dimensional, GIS. A means of abstract description of the topological and geometric part of space data is modelled, either presentation of space data or their structure. The most widespread model, the relational one, which presents the space data attributes in databases, is the correlational data model. The quality of space data is determined by their accuracy (correctness), reliability, authenticity, completeness and non-contradiction. On the basis of space data, the basic functional capabilities of GIS are defined, including operations of inputting, exporting, importing, exchanging, pre-processing, processing, analyzing, outputting, visualizing, etc.

According to the interpretive dictionary of basic Geoinformatics terms, GIS (geographic information system, Geoinformation system) is:

- 1) The information system that ensures space-coordinated (space) data collection, storage, processing, access, presentation and spread. GIS contain a digital presentation of data on space objects (vector, raster, quadrotomic, etc.);
- 2) A software means in which functional capabilities of GIS are realized. It obtains software, hardware, legal, staff and organizational support.

GIS can be classified by:

- *Area coverage*: global (planetary), sub-continental, national (state), regional, sub-regional, local;
- *Subject area*: city (municipal), nature-saving (land, in particular), etc.;
- *Problem orientation*: scientific (GIS for data analysis and assessment), applied (GIS for resource inventory, monitoring, control and planning, decision-making support).

Geoinformatics training can be performed at several levels:

- 1) The level of subject-oriented training at general upper secondary schools;
- 2) The level of professional training of specialists in geography, geodesy, cartography and land management, for whom Geoinformatics is a standard subject;
- 3) The level of professional training of specialists in other fields of training, for whom Geoinformatics is not a standard subject.

Thus, we can draw a conclusion that Geoinformation technologies training should meet the following requirements:

- 1) *Professional conditionality*: the need of teaching Geoinformation technologies, according to one's field of study, should be well grounded;
- 2) *Professional orientation*: the content of the geoinformation technologies training should be connected with future specialists' professional competences;
- 3) *Social significance*: the Geoinformation technologies training should be determined by the concept of sustainable development.

The professional conditionality of future mining engineers' Geoinformation technologies training is determined by the fact that, firstly, "Mine Surveying" is one of mining specialties, and, secondly, "Mine Surveying Support of Mining Production" is a standard part of general engineering and professional-practical training in the field of study 050301 "Mining", which implies studying such conceptual modules as [27, p. 176]:

1. Mine surveying graphic and calculating documentation.
2. Technology of applying mine surveying measurements on the surface and in underground mine workings.
3. Mine surveying operations in prospecting and oil and gas production.
4. Mine surveying operations in constructing a technological complex of a mining enterprise.
5. Mine surveying operations in mine sinking and drifting.
6. Mine surveying operations in open pit mining.
7. Mine surveying operations in underground mining.
8. Deposit geometrization, mineral reserves calculation, mine surveying control and recording.

"Small Encyclopedia of Mining" defines mine surveying as a branch of mining science and engineering that deals with spatial and geometric measurements (mine surveys) underground and at corresponding sites of the surface with the purpose of:

- depicting the Earth surface situations and relief at the sites of mineral deposits, prospecting and mining workings, objects built on the surface in plans, projections and sectional drawings;
- solving various mining engineering and geometrical tasks arising on all stages of the deposit mining and mining enterprises' closing;
- studying the character of landslides and deformations of the surface and rocks, determining the measures for protecting buildings from the harmful influence of mining workings.

Mine surveying data is used to design mining operations, deposit opening and complex mining, calculate mineral quantity and quality, make up mining calendar plans and when building underground facilities not connected with mineral mining [28, p. 69-70; 38].

Thus, the professional orientation of teaching geoinformation technologies for future mining engineers is determined, first of all, by the necessity of forming the professional competence (the ability to determine spatial and geometric location of objects, perform necessary geodesic and mine surveying measurements, process and interpret their results).

Application of Geoinformation technologies means in mining engineers' professional activity allows not only considering the location of a mining enterprise's subdivisions, mineral stockpiles and rock dumps, but also enhancing the satisfaction of environmental requirements for mining operations [2, Article 34]:

- monitoring sewage water and return air treatment, while introducing advanced mining technologies;
- modelling the organization of sanitary zones between a mining enterprise and residential buildings according to in-force legislation;
- providing complex measures preventing subsidence, inundation, swamping, salting, draining and pollution of the surface by industrial waste;

- preventing a harmful influence of water removal from mine workings to the level of ground waters and surface water objects;
- monitoring the reduction of pollutant emissions and releases during mining operations and taking steps for preventing accidents caused by volley and immediate emissions and releases.

Thus, meeting the requirements of the professional conditionality, professional orientation and social significance for teaching Geoinformation technologies calls for the development of the training content of the special course “Environmental Geoinformatics”, which is a component of the system of creating future mining engineers’ environmental competence.

2. THE RESULTS AND DISCUSSION

The research program had three stages:

- 1) analytical-ascertaining;
- 2) designing-searching;
- 3) forming-generalizing.

The first stage of the experimental research studied the current state of the investigated phenomenon and created the initial statements of the research. To perform the set task, the authors analyzed higher education standards, training programs, and curricula, as well as monographs and course books on ecology, geoinformation technologies, mining, scientific and methodological literature on issues of forming a mining student’s environmental competence, practices of training mining engineers, etc. The analyzed data indicated the relevance of the research and its hypothesis.

At the analytical-ascertaining stage, the authors focused on teaching ecology at secondary and higher school (in particular, environmental and ethnographic materials concerning the Prydniprovskiy region), ICT tools for teaching ecology, the application of geoinformation technologies, issues regarding the development of professional trends in training, and assessing the quality of training future mining engineers.

The results of the analytical-ascertaining stage of the pedagogical experiment revealed the following:

1. Ukrainian mining engineers are trained according to industry-based higher education standards, which are not based on the competence approach. Considering the fact that the investigated phenomenon – a future mining engineer’s environmental competence – is an integrated personal formation, which includes professional environmental knowledge, environmentally safe mining operations, sustainable development, and socially responsible environmental behavior, there arises a need to create new standards based on the competence approach.
2. The basic components of a future specialist’s environmental competence (ethical standards of behavior with regard to other people and nature (i.e., bioethics principles) and environmental literacy) are formed at secondary school and later at university when studying ecology and professional-orientated subjects.
3. In spite of the availability of professional-oriented geoinformation technologies in mining and environmental activities, they are mostly used in the final stage of professional training when studying majors and preparing a diploma project.

These contradictions affected the research goal, as well as the formation of tasks centred on increasing the use of geoinformation technologies.

Therefore, the second stage of the experimental research aimed to design and develop a system of competences for future mining engineers. It also distinguished the corresponding components that make up environmental competence.

To estimate the adequacy of the current system, 59 training experts were questioned. The expert group included 11 professors, 31 associate professors, 8 senior lecturers, 9 assistants from Kryvyi Rih National University, National Technical University of Ukraine “Kyiv Polytechnic Institute”, Kharkiv National University of Building and Architecture, the National Metallurgical Academy of Ukraine and the SE “SPI “Kryvbasproekt”. Figure 3 reveals the distribution of experts according to the number of years of their teaching experience at university.

Each competence was estimated according to the following scale: –2 (absolutely insignificant), –1 (more likely insignificant), 0 (no answer), 1 (more likely significant), 2 (very significant). The sum of all experts’ estimates for each competence enabled the total assessment within the range to be determined (–2; 2) as well as the competence contribution to the general system of competences (Table 1).

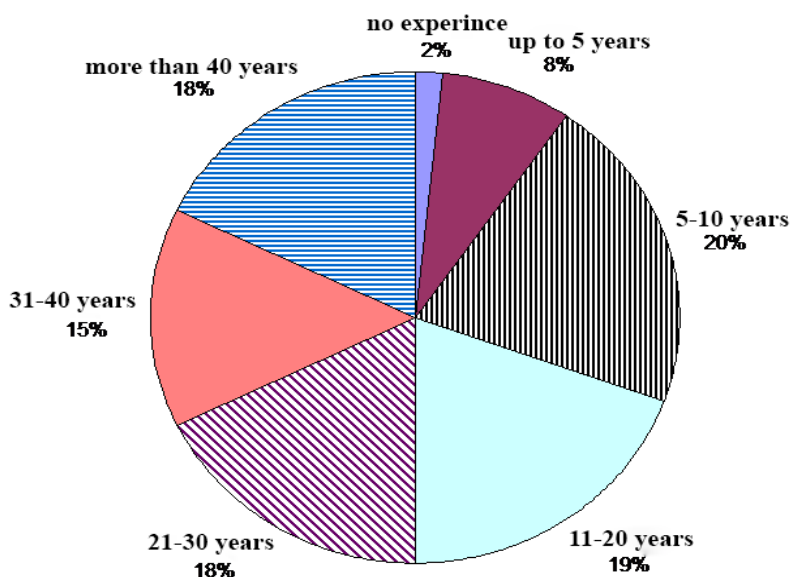


Fig. 3. The distribution of experts according to the number of years spent training mining specialists at higher education institutions

Each component of environmental competence was assessed by the 100-point scale (Table 1) according to the formula:

$$EC_i = (100/3) (C_i \cdot A_{C_i} + P_i \cdot A_{P_i} + A_{X_i} \cdot A_{A_{X_i}} + S_i \cdot A_{S_i}),$$

where i is the number of the environmental competence components ($i=1, 2, 3, 4, 5$); EC_i is assessment of the i -th component of the environmental competence ($EC_i = 0 \dots 100$); C_i , P_i , A_{X_i} , S_i signify the cognitive (C), praxeological (P), axiological (A), and social-behavioural (S) criteria of the i -th component maturity of the environmental competence according to Table 2 ($C_i, P_i, A_{X_i}, S_i = 0 \dots 1$). A_{C_i} , A_{P_i} , A_{A_i} , A_{S_i} are an assessment of the i -th component maturity of the environmental competence according to the cognitive (C), praxeological (P), axiological (A), and social-behavioural (S) criteria (0 – low, 1 – medium, 2 – sufficient, and 3 – high).

The multiplier 100/3 is normalizing the following: division by 3 brings the assessment into the range of 0.1, while multiplication by 100 brings it into the range of 0.100.

Table 1.

The correspondence of levels in environmental competence maturity to the 100-point scale

Levels of maturity	Points	
	min	max
0 – low	0	49
1 – medium	50	64
2 – sufficient	65	89
3 – high	90	100

Table 2.

Contribution of components to the formation of a future mining engineer's environmental competence

No.	Component	Fraction
1	An understanding and perception of ethical standards of behavior with regard to other people and nature (bioethics principles)	0.211
2	Environmental literacy	0.219
3	A basic knowledge of ecology to be applied to one's professional activities	0.208
4	The ability to apply scientific laws and methods when assessing the environment; take part in environmental operations; perform an environmental analysis of measures in professional activities; work out plans of operations to reduce the technogenic pressure on the environment	0.159
5	The ability to ensure sustainable activities, and master methods of rational and complex development of georesources	0.203

The total assessment of environmental competence is calculated by the formula:

$$EC = \sum_{i=1}^5 Con_i \cdot EC_i, \quad (1)$$

where i is the number of the environmental competence components ($i=1, 2, 3, 4, 5$); EC_i is assessment of the i -th component of the environmental competence ($EC_i = 0 \dots 100$); Con_i is contribution of the i -th component of the environmental competence to its formation according to Table 3 ($Con_i = 0.1$).

Table 3.

Significance of each criterion when forming a future mining engineer's environmental competence

No.	Component	Criterion			
		C	P	A	S
1	An understanding and perception of ethical standards of behavior with regard to other people and nature (bioethics principles)	0.20	0.20	0.35	0.25
2	Environmental literacy	0.40	0.30	0.20	0.10
3	An ability to apply a basic knowledge of ecology to one's professional activity	0.45	0.20	0.25	0.10
4	The ability to apply scientific laws and methods when assessing environmental conditions, to take part in environmental operations, to perform an environmental analysis of the steps in the field of activity, to work out the plan in order to reduce technogenic pressure on the environment	0.35	0.50	0.10	0.05
5	The ability to ensure sustainable activities, and the rational and complex development of georesources	0.30	0.30	0.25	0.15

The results of the designing-searching stage indicated whether the experiment could pass to the third stage of the research. The formation stage of the pedagogical experiment aimed to introduce methods to apply geoinformation technologies to help form a future mining engineer's environmental competence. 150 second-year students from the mining faculty of Kryvyi Rih National University studied the special course, "Environmental Geoinformatics". In control groups at laboratory classes in the special course, multifunctional geoinformation systems were used; in experimental groups both GIS and mining-environmental systems were applied. The experimental groups were also given an additional software-methodological complex, "EcoKryvbas", for independent work.

The results of the formation stage of the experiment in the control and experimental groups are given in Table 4.

Table 4.

The comparative distribution of students by the level of environmental competence maturity in the control and experimental groups

Level	Before the formation stage of the pedagogical experiment				After the formation stage of the pedagogical experiment			
	Control groups		Experimental groups		Control groups		Experimental groups	
	Num-ber	%	Num-ber	%	Num-ber	%	Num-ber	%
The first component								
low	9	12%	8	10.67%	3	4 %	1	1.33%
medium	18	24 %	25	33.33%	12	16 %	2	2.67%
sufficient	45	60 %	36	48 %	55	73.33%	50	66.67%
high	3	4 %	6	8 %	5	6.67%	22	29.33%
The second component								
low	28	37.33%	29	38.67%	14	18.67%	11	14.67%
medium	23	30.67%	24	32 %	24	32 %	22	29.33%
sufficient	20	26.67%	15	20 %	32	42.67%	27	36%
high	4	5.33%	7	9.33%	5	6.67%	15	20 %
The third component								
low	28	37.33%	29	38.67%	14	18.67%	11	14.67%
medium	23	30.67%	24	32%	24	32 %	22	29.33%
sufficient	20	26.67%	15	20%	32	42.67%	27	36%
high	4	5.33%	7	9.33%	5	6.67%	15	20%
The fourth component								
low	65	86.67%	66	88%	61	81.33%	24	32%
medium	8	10.67%	6	8%	11	14.67%	31	41.33%
sufficient	2	2.67%	3	4%	3	4%	18	24%
high	0	0 %	0	0%	0	0%	2	2.67%
The fifth component								
low	65	86.67%	67	89.33%	67	89.33%	36	48%
medium	7	9.33%	6	8%	6	8%	26	34.67%
suffi-cient	3	4%	2	2.67%	2	2.67%	10	13.33%
high	0	0%	0	0%	0	0%	3	4%
Environmental competence								
low	35	46.67%	41	54.67%	23	30.67%	13	17.33%
medium	31	41.33%	23	30.67%	37	49.33%	27	36%
sufficient	9	12%	10	13.33%	15	20%	28	37.33%
high	0	0%	1	1.33%	0	0%	7	9.33%

Comparative histograms of the distribution of students by the level of the environmental competence maturity are given in Figures 4-6.

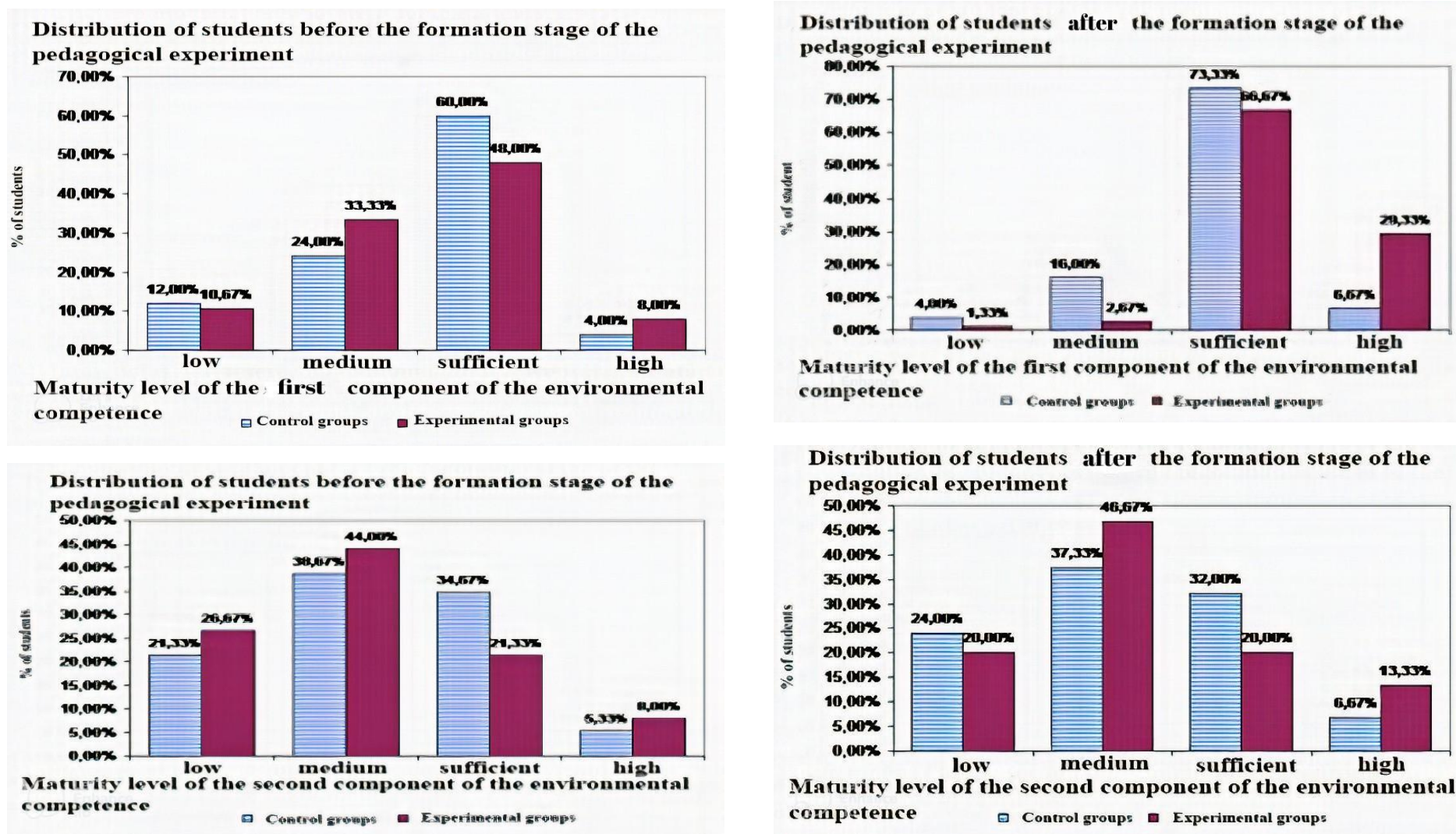


Fig. 4. The distribution of students in the control and experimental groups before and after the formation stage of the pedagogical experiment and according to the maturity level of the first and second components of environmental competence

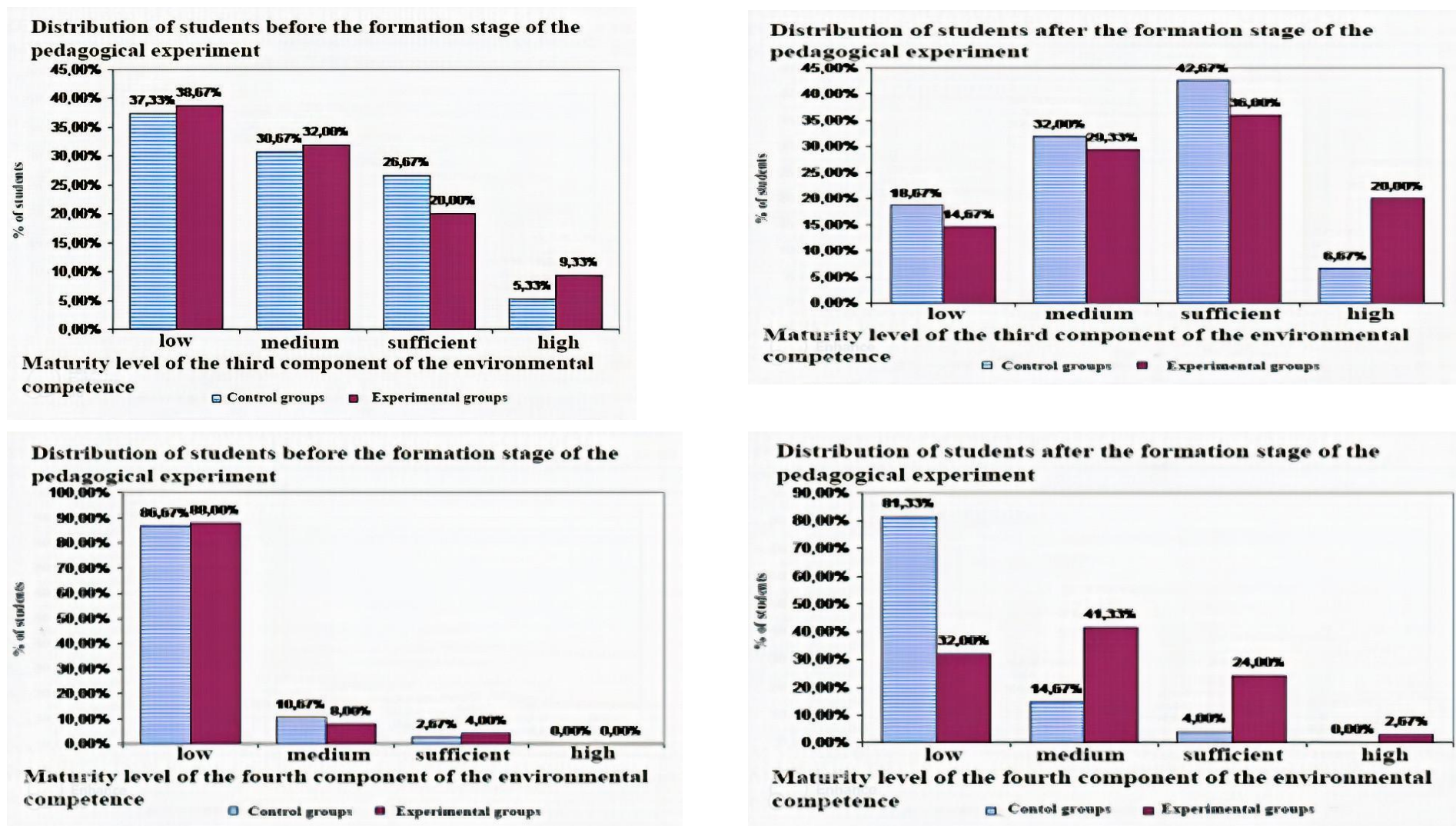


Fig. 5. The distribution of students in the control and experimental groups before and after the formation stage of the pedagogical experiment, according to the maturity level of the third and fourth components of environmental competence

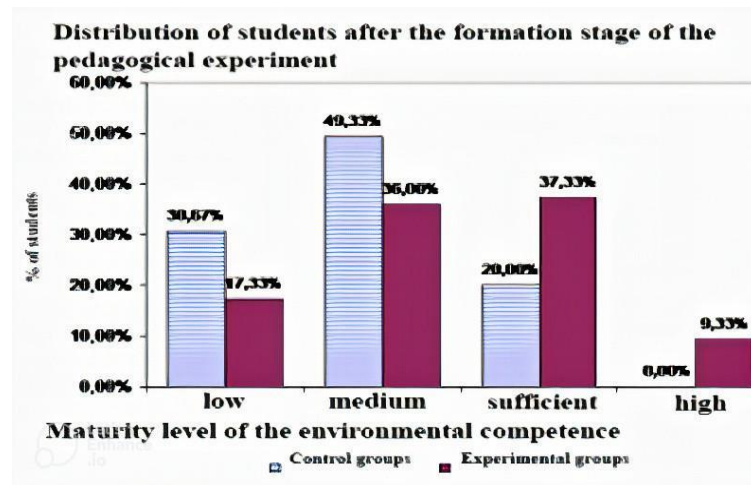
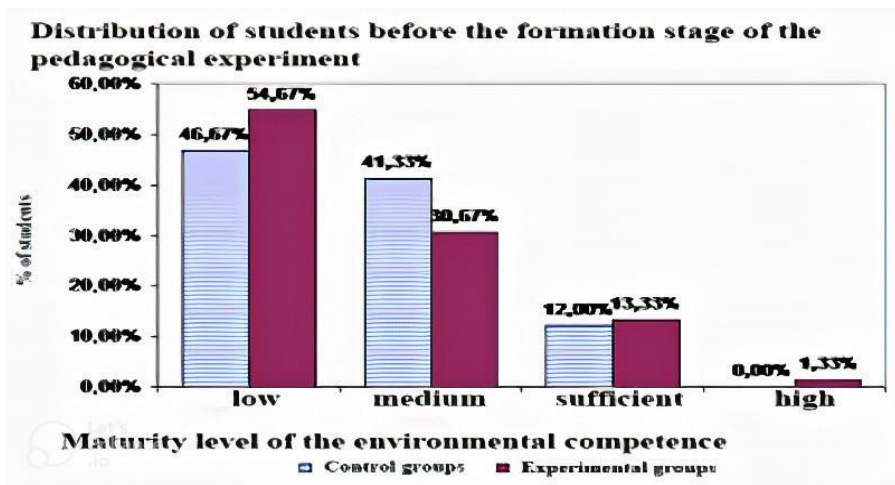
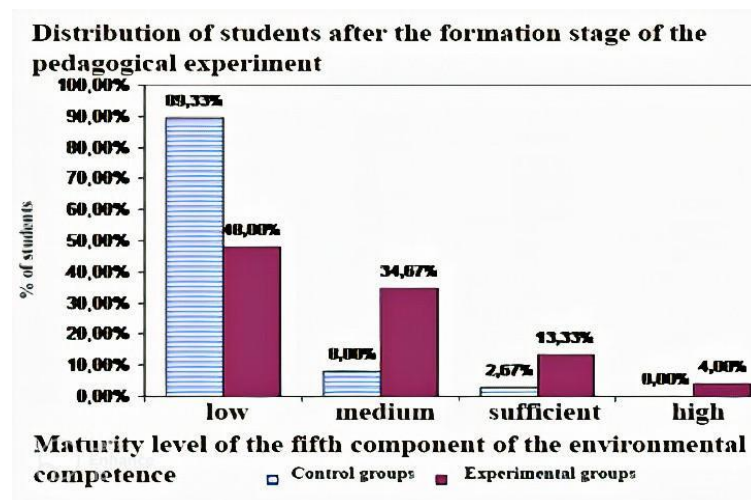
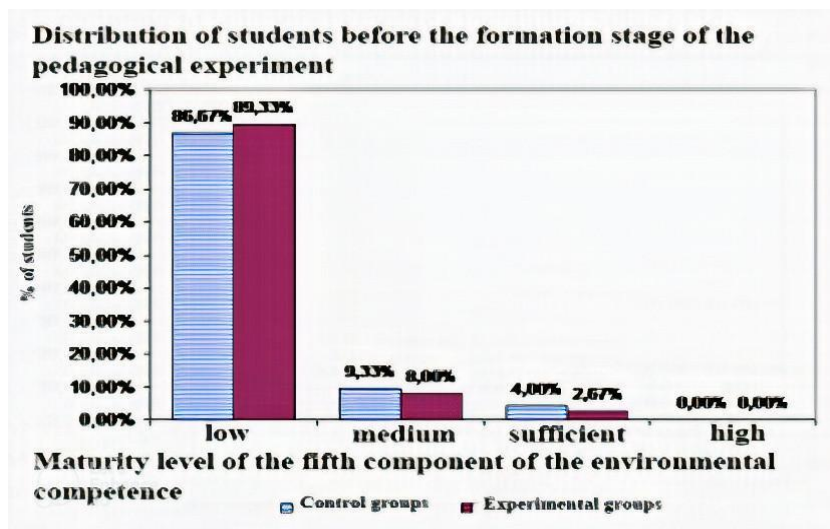


Fig. 6. The distribution of students in the control and experimental groups before and after the formation stage of the pedagogical experiment, according to the maturity level of the fifth component of environmental competence, and as a whole

3. CONCLUSIONS AND PROSPECTS OF FURTHER RESEARCH

1. The problem of using geoinformation technologies in the process of forming the environmental competence of future mining engineers has not been considered before.
2. The concept of "geoinformation ICT" is clarified as a set of methods, tools and techniques used to collect, systematize, store, process, transmit and present spatially coordinated messages and data.
3. The experimental research program aimed at checking the efficiency of the methods used to apply Geoinformation technologies when forming environmental competence was realized in three stages: analytical-ascertaining, designing-searching, and forming-generalizing.

The discrepancies found in the analytical-ascertaining stage of the pedagogical experiment (between current industry-based standards using the knowledge approach and competence-based standards; between the pedagogical potential of geoinformation technologies and their underdeveloped application; ignoring the demand for environmentally safe mining activity and sustainable development in the current standards) required a new system of competences to be developed with separate environmental competence components.

In order to evaluate the adequacy of the competency system during the designing-searching stage of the pedagogical experiment, the authors conducted an assessment, which revealed the following:

- The contribution of each competence was as follows: social-personal – 23.34 %, general scientific – 9.92 %, instrumental – 9.47 %, general professional – 39.66 %, specialized professional – 16.61 %
- The contribution of each component to the creation of a future mining engineer's environmental competence was as follows: the first component – 21.08%, the second component – 21.85%, the third component – 20.82%, the fourth component – 15.94%, the fifth component – 20.31%. The formation of the professional competence was 11.06%
- The contribution of cognitive, praxeological, axiological, and social-behavioral criteria when forming a future mining engineer's environmental competence was as follows: when forming the first component, axiological is the leading criterion; when forming the second and the third component, it is the cognitive criterion; when forming the fourth component it is the praxeological criterion; when forming the fifth component it is the cognitive and praxeological criteria.

The formation stage of the pedagogical experiment introduced the application of geoinformation technologies to create environmental competence in the special course in Environmental Geoinformatics. In the laboratory lessons of the control groups, multifunctional geoinformation systems were used, while the experimental groups used multifunctional GIS, mining and environmental GIS, and the software component of the "EcoKryvbas" methodological complex. After completing the experimental training, it was found that 49.33% of the students in the control groups achieved a medium level of environmental competence maturity, 20% achieved a sufficient level, while in the experimental group, 37.33% achieved a sufficient level and 36% a medium level.

4. The issue of implementing geoinformation technologies at the State Tax University of Ukraine requires further research.

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Text of the article was accepted by Editorial Team 16.02.2023 p.

ГЕОІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ У НАВЧАННІ МАЙБУТНІХ ГІРНИЧИХ ІНЖЕНЕРІВ

Моркун Володимир Станіславович

доктор технічних наук, професор

Байройтський університет, м. Байрот, Німеччина

ORCID ID 0000-0003-1506-9759

morkunv@gmail.com

Семеріков Сергій Олексійович

доктор педагогічних наук, професор
професор кафедри інформатики та прикладної математики
Криворізький державний педагогічний університет, м. Кривий Ріг, Україна
ORCID ID 0000-0003-0789-0272
semerikov@gmail.com

Грищенко Світлана Миколаївна

кандидат педагогічних наук, старший дослідник,
доцентка кафедри комп'ютерних та інформаційних технологій і систем
Державний податковий університет, м. Ірпінь, Україна
ORCID ID 0000-0003-4957-0904
s-grischenko@ukr.net

Анотація. Сучасна людина не може жити без цифрових технологій, які досягли небувалого розквіту. Постійне зростання інформації призвело до того, що з'явилося багато можливостей для цифрових транзакцій у різних професіях, одна з яких - гірничий інженер. Процес реформування цієї професії потребує більш ефективного використання цифрових технологій в екології, забезпечення інформаційного менеджменту шляхом впровадження інновацій, створення баз даних, програм, впровадження яких дозволить підвищити якість управління інноваційними процесами. Стимулювання абітурієнтів до вступу в заклади вищої освіти на інженерні спеціальності шляхом надання додаткових пільг свідчить про зацікавленість країни у збільшенні кількості інженерів. У професійній діяльності інженерів гірничого профілю саме інформаційні технології надають можливість не лише розглядати розташування виробничих підрозділів гірничого підприємства, складів корисних копалин і відвалів порід гірничого підприємства на будь-якому необхідному рівні деталізації, а й сприяти задоволенню основних екологічних вимог у сфері проведення гірничих робіт. Програма експериментального дослідження з метою перевірки ефективності методів застосування геоінформаційних технологій при формуванні екологічної компетентності реалізовувалась у три етапи: аналітико-констатувальний, проектно-пошуковий та формувально-узагальнюючий. Розбіжності, виявлені на аналітико-констатувальному етапі педагогічного експерименту, вимагали розробки нової системи компетентностей з окремими компонентами екологічної компетентності. На лабораторних заняттях контрольних груп використовувалися багатофункціональні геоінформаційні системи, а в експериментальних – багатофункціональні ГІС, гірничо-екологічні ГІС та програмна складова методичного комплексу «ЕкоКривбас». Після завершення експериментального навчання встановлено, що 49,33% учнів контрольних груп досягли середнього рівня екологічної компетентності. 20% досягли достатнього рівня, тоді як в експериментальних групах 37,33% учнів досягли достатнього рівня і 36% досягли середнього рівня. У продовженні наукових досліджень даної проблеми доцільно розробити методичну систему навчання геоінформаційних технологій для студентів спеціальності 122 «Комп'ютерні науки».

Ключові слова: геоінформаційні технології; педагогічний експеримент; цифрові технології; гірничий професійний інженер.

