Results of Experimental Work to Check the Effectiveness of the Method of Using Geoinformation Technologies

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Abstract: A modern person cannot live without the Internet, namely without digital technologies. The constant growth of information has led to the fact that there are many opportunities for digital transactions in various professions, one of them is a mining engineer. The process of reforming this profession requires more effective use of digital technologies in ecology, providing information management through introduction of innovations, creation of databases, programs, 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. The article presents the results of the formula stage of the pedagogical experiment on checking the effectiveness of the method of using geoinformation technologies as a means of forming ecological competence of future engineers of the mining profile using the Pearson's χ^2-criterion, the Kolmogorov-Smirnov's λ-criterion and Fischer's ϕ^*-criterion. It is clear that the distribution of students in experimental and control groups by the level of environmental competence is statistically significant, due to the application of the developed methodology. In continuation of scientific search on this problem, it is expedient in the direction of development of methodical system of training of geoinformation technologies in students of specialty 122 "Computer sciences".

1 INTRODUCTION

The use of information and communication technologies in education at the present stage, undoubtedly, can be a catalyst in the solution of important social problems of increasing accessibility and quality of educational resources and services. The constant increase in the amount of information and the speed of transmission of information flows through digital communication networks remains as important as ever. Information technology has reached an unprecedented level of sophistication. Everything has changed with the arrival of the Internet in every home. Modern people of any age can no longer do without the Internet. The information space provides a lot of opportunities to perform all possible operations while staying in the office or an apartment.

Many professions are obliged to their appearance in computer, they would simply not appear without the creation of digital technologies.

If we consider the profession of an engineer – a person who is engaged in engineering activity, i.e., in particular, different researches, designing, development of various documentation and conducting of a huge number of calculations, for very complex calculations, which even when using the computer equip-

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ment's capabilities are hours and days, but without its use or would be decided for many months, or could not be realized at all (Semerikov et al., 2021).

Legal and organizational principles of mining engineering activity are defined by the Mining Law of Ukraine (zak, 2020), according to which the state policy in mining industry is based, in particular, on the principles of improvement of ecological safety of mining enterprises and provision of training of personnel of high qualification for mining industries. The level of ecological state in the country has become dangerous not only for the present, but to a greater extent for future generations. The negative impact of harmful environmental factors on the human body is the deterioration of the health of the nation.

The main environmental requirements in the field of mining work, prevention of harmful effects of mining work and ensuring environmental safety during mining work are not only the subject of consideration of separate articles of the Ukrainian Mining Law, but also the obligatory components of preparation of an environmentally competent engineer of the mining profile.

The problem of forming the environmental competence of the practitioner has been the subject of research at different levels, such as (Orr, 1992; Bofinger, 2006; Harvey, 2002).

Various aspects of professional training of mining engineers were investigated in (Bidiuk, 2000; Medvedovska, 2012; Derevianko, 2013; Morkun et al., 2014; Hryshchenko and Morkun, 2015; Morkun et al., 2017).

The problem of using information and communication technologies in training of mining engineers of the mining profile is especially urgent today. The process of reform requires more efficient use of digital technologies in the environment, providing information management through introduction of innovations, creation of databases and programs, which implementation will help to improve the quality of management of innovation processes. One of the promising directions of solving this problem is the use of geoinformation technologies.

An analysis of the recent studies and publications on the investigated issues reveals that the use of modern geoinformation technologies was investigated by Kulibekova (Kulibekova, 2008), Hryshchenko and Morkun (Hryshchenko and Morkun, 2015), Morkun et al. (Morkun et al., 2014, 2017) and other scientists.

However, the peculiarities of using geoinformation technologies in teaching and conditions of their introduction into the state administration of ecology and mining in scientific literature are not covered enough.

One of the promising ways of solving this task is application of geoinformation technologies that allow considering the location of a mining enterprise's facilities, mineral storages and rock dumps on any required detail level; monitoring discharged water and air purification while introducing advanced mining methods; simulation of a sanitary protection area between a mining enterprise and residential buildings in accordance with the law; ensuring complex steps for preventing subsidence, submergence, salting, salting, draining and pollution of the surface by industrial wastes; preventing unfavourable influence of water removal on the level of ground waters and surface water objects; monitoring the decreased pollutant emissions in the mining industry and introducing accident prevention measures associated with volley and immediate emissions and releases, etc.

The **purpose** of the article is to highlight the results of experimental work on the verification of effectiveness of the method of using geoinformation technologies as a means of forming ecological competence of realization of future engineers of the mining profile using the Pearson's χ^2-criterion, Kolmogorov-Smirnov's λ-criterion and Fischer's ϕ^{**}-criterion.

At the time of scientific and pedagogical workers should be ready to use digital technologies in teaching, which help to define the following approaches of students of engineering specialties formation of motivation, intensification of cognitive activity, professional orientation and creativity in teaching, remote complex application of methods and means, and also assessment of quality and systematization of control.

2 MATERIALS AND METHODS

In order to achieve the set goal, the following research methods were used: theoretical analysis of different views of scientists; statistical, generalization of results.

3 EXPERIMENTS

The purpose-oriented creation of a future mining engineer's environmental competence using geoinformation technologies occurs in the special course, Environmental Geoinformatics. The three-component structure of its method system is the central element that determines the training content and goals which, together with the training technology are made concrete in the special course, Environmental Geoinformatics. The special course goal is to create environmental competence through specific knowledge and skills, thereby, providing students with the opportunity to use geoinformation technologies both in their learning activities and then, later, in their professional lives. The special course goals are determined by the following tasks: introduction of basic models and methods of geoinformatics, mastering the modern means of geoinformation technologies in one's professional activities, and the formation of environmental research skills using geoinformation technologies.

The basic forms of training that use geoinformation technologies include lectures, demonstrations, frontal laboratory works, laboratory and calculation "immersion" practicals, seminars, practical classes, projects, consultations, training excursions, simulation games, and independent work. Among these training methods, the leading ones are demonstrative examples, reasonably chosen tasks, a calculation experiment, and projects.

The choice of training (with regard to geoinformation technologies in particular) is determined by the peculiarities of its creation on different stages. In the first stage geoinformation technologies such as cartographical software (Google Maps, Google Earth) and Internet sources with geographical and environmental data (with regional specific features in the field of professional activity) are used. In addition, in the course, "Informatics", students learn how to deal with electronic tables and databases as means of working with table space and coordinated data; they also use search engines to gather geographical and environmental data and to put this into a system. Computer mathematics systems (MATLAB as the basis of the multifunctional GIS Mapping Toolbox) are also used. Training used in the second stage of creating a future mining engineer's environmental competence are divided into general (course books, Internet sources, means for creating, storing, processing text, table and graphic data, and Moodle) and specific purposes (cartographical software such as Google Maps and MapInfo; multifunctional such as Mapping Toolbox and QGIS; and mining and environmental GIS such as Datamine Studio and Geoblock). At the third stage of creating environmental competence, all of the geoinformation technologies mastered in the previous stages are used; however, special attention is paid to the application of mining and environmental GIS (Datamine Studio, Geoblock, K-MINE, etc.).

The pedagogical experiment results were processed and the efficiency of the developed methods of training mining students was assessed using mathematical statistical methods. As the research aimed to determine differences in feature distribution (the level of maturity of the environmental competence) when comparing two empirical distributions (students in the control and experimental groups) (Sidorenko, 2003, p. 34), either the Pearson's χ^2-criterion, or the Kolmogorov-Smirnov's λ-criterion and ϕ^{**}-criterion (Fischer's angular transformation) can be used.

The Fischer's angular transformation was calculated according to table 1:

1. Before the formation stage of the pedagogical experiment:
   - in the control groups, 66 students (88%) had low and medium maturity levels of environmental competence and 9 students (12%) had sufficient and high levels;
   - in the experimental groups, 64 students (85.33%) had low and medium levels of maturity of environmental competence and 11 students (14.67%) had sufficient and high levels.
2. After the formation stage of the pedagogical experiment:
   - in the control groups (CG), 60 students (88%) had low and medium maturity levels of environmental competence and 15 students (20%) had sufficient and high levels;
   - in the experimental groups (EG), 40 students (53.33%) had low and medium maturity levels of environmental competence and 35 students (46.67%) had sufficient and high levels.

The experimental data completely met the restrictions of the Fischer's angular transformation:

a) any compared fraction is not equal to zero;

b) the number of observations in both selections is more than five, which enables any comparison.

Let us formulate hypotheses (H).

H_0: The fraction of students whose environmental competence is at the sufficient and high levels was not greater in the experimental groups than in the control ones.

H_1: The fraction of students whose environmental competence is at the sufficient and high levels was greater in the experimental groups than in the control ones.

The below formula was applied:

$$\phi^*_{emp} = 2\left|\arcsin\sqrt{P} - \arcsin\sqrt{Q}\right|\sqrt{\frac{n_1 n_2}{n_1+n_2}},$$

where P and Q are the percentage of students whose environmental competence is sufficient or high, $n_1 = n_2 = 75$ is the number of students in the control and experimental groups. Therefore:

1. Before the formation stage of the pedagogical experiment: $\phi^*_{emp} = 0.481$.

Table 1: The comparative distribution of students by the level of environmental competence maturity in the control and experimental groups.

Level	Before the formation stage				After the formation stage			
	CG		EG		CG		EG	
	Number	%	Number	%	Number	%	Number	%
The first component: Understanding and perception of ethical norms of behavior with regard to other people and nature (principles of bioethics)								
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: Environmental literacy								
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: A basic knowledge of ecology to be applied in one's professional activities								
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: The ability to apply scientific laws and methods to assess the condition of the environment, take part in environmental operations, perform an environmental analysis of steps in the field of activity, and to work out plans to reduce technogenic pressure on the environment								
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: The ability to ensure sustainable activities, and methods for the rational and complex development of georesources								
low	65	86.67%	67	89.33%	67	89.33%	36	48%
medium	7	9.33%	6	8%	6	8%	26	34.67%
sufficient	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%

2. After the formation stage of the pedagogical experiment: $\phi^*_{emp} = 3.532$.

The critical value of ϕ^*_{cr} corresponds to the level of statistical significance established in psychological and pedagogical investigations, and is equal to

$$\phi^*_{kr} = \begin{cases} 1.64 \ (p \leq 0.05) \\ 2.31 \ (p \leq 0.01) \end{cases}$$

Then:

1. Before the formation stage of the pedagogical experiment, the inequality $\phi^*_{emp} < \phi^*_{cr}$ is realized and this provides the evidence for accepting the zero hypothesis H_0 and stating that before the formation stage of the pedagogical experiment, the difference in the maturity level of students' environ-

mental competences from the control and experimental groups is statistically insignificant (figure 1): i.e., the control and experimental groups before the formation stage of the pedagogical experiment coincide with the significance level of 0.05.

2. After the formation stage of the pedagogical experiment the inequality $\phi^*_{emp} < \phi^*_{cr}$ is realized thereby providing the evidence to reject the zero hypothesis H_0 and accept the alternative H_1. Considering the fact that $\phi^*_{emp} = 3.532 > 2.31 = \phi^*_{0.01}$, we have obtained the following result: the validity of differences in the experimental and control groups after the formation stage of the pedagogical experiment is 0.99 (figure 2).

4 RESULTS

Therefore, after the formation stage of the pedagogical experiment, students from the control and experimental groups have statistically significant differences with regard to the sufficient and high maturity levels of environmental competence that result from the application of the suggested methods.

To find out the difference in distribution of maturity levels in environmental competence, we applied the Pearson's χ^2-criterion.

In our research, the samples are random and independent. Considering the fact that intervals with zero frequencies are unacceptable and not less than 80% of frequencies should be more than 5, the "sufficient" and "high" levels were united. The measurement scale is the one with $C = 3$ levels (1 is "low", 2 is "medium", 3 is "sufficient and high"). One independent condition was imposed and the number of freedom degrees was $\nu = C–1 = 2$.

The zero hypothesis was H_0 and therefore, the probability of the control group students ($n_1 = 75$) and those of the experimental one ($n_2 = 75$) getting into each of i ($i = 1,2,3$) categories is equal: i.e., H_0: $p_{1i} = p_{2i}$ ($i = 1,2,3$), where p_{1i} is the probability of maturity of the control group's environmental competence on the i level ($i = 1,2,3$) and p_{2i} the probability of formation of the experimental groups' environmental competence on the i level ($i = 1,2,3$).

The alternative hypothesis implies H_1: $p_{1i} \neq p_{2i}$, at least for one of C categories.

The value of χ^2 is calculated by the formula:

$$\chi^2 = \frac{1}{n_1 n_2} \sum_{i=1}^{C} \frac{(n_1 Q_{2i} - n_2 Q_{2i})^2}{Q_{1i} + Q_{2i}}$$

where Q_{1i} is the number of the control group participants with the environmental competence formed at the i level; Q_{2i} is the number of the experimental group participants with the environmental competence formed ar the i level.

Let us denote

$$S_{12i} = \frac{(n_1 Q_{2i} - n_2 Q_{2i})^2}{Q_{1i} + Q_{2i}}$$

Calculation results of the given samples are in table 2.

Table 2 shows that the χ^2 values of the freedom degrees number provides the critical value of the statistics: the significance level of $\alpha = 0.05$, $\chi^2_{0.05} = 5.99$; the significance level of $\alpha = 0.01$, $\chi^2_{0.01} = 9.210$.

As before the formation stage of the pedagogical experiment the value is $\chi^2 < \chi^2_{0.05}$ ($1.859 < 5.991$), it does not occur in the critical zone. The acceptance of the hypothesis, H_0, reveals that before the formation stage of the pedagogical experiment, the control and experimental groups with a significance level of 0.05 are not different in the three formation levels of environmental competence.

The calculation of the χ^2 criterion for the experimental and control samples, after the formation stage of the pedagogical experiment, reveals that $\chi^2 > \chi^2_{0.05}$ ($12.340 > 5.991$) and $\chi^2 > \chi^2_{0.01}$ ($12.340 > 9.210$). It is the reason for rejecting the zero hypothesis H_0. Acceptance of the alternative hypothesis H_1 involves stating that the samples have statistically significant differences with the significance level of 0.01: i.e., the developed methods of applying geoinformation technologies to training future mining engineers enhance the maturity level of their environmental competence.

To find out the level of maximum differences, we checked the samples according to the Kolmogorov-Smirnov's λ-criterion, which is not parametric and applied if:

- samples are random and independent;
- categories are arranged by an increasing or decreasing order.

The given conditions are fulfilled for the obtained samples and the λ-criterion can be applied to assess the deviation of distribution in the experimental groups and the control groups in all four levels.

Let us denote $F(x)$ as the unknown distribution function of probabilities with regard to the maturity level of a future mining engineer's environmental competence in the control groups and $G(x)$ as the unknown distribution function of probabilities in the experimental groups.

The zero hypothesis implies H_0: $F(x) = G(x)$. The alternative hypothesis implies H_1: $F(x) \neq G(x)$. When the hypothesis H_0: $F(x) = G(x)$ is fulfilled, the deviation $D = \sup_x |G(x) - F(x)|$ is small and when the hypothesis is not fulfilled, this deviation is great.

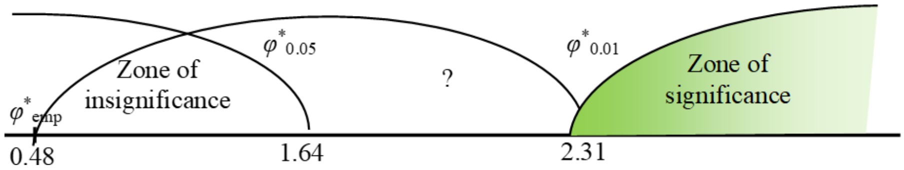

Figure 1: The significance axis for the ϕ^*-criterion before the formation stage of the pedagogical experiment.

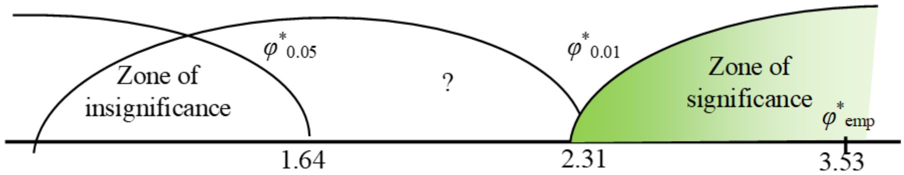

Figure 2: The significance axis for the ϕ^*-criterion after the formation stage of the pedagogical experiment.

Table 2: Calculation of χ^2-criterion.

i	Before the formation stage			After the formation stage		
	Q_{1i}	Q_{2i}	S_{12i}	Q_{1i}	Q_{2i}	S_{12i}
1 – low	35	41	2664.474	23	13	15625
2 – medium	31	23	6666.667	37	27	8789.063
3 – sufficient and high	9	11	1125	15	35	45000
χ^2			**1.859**	χ^2		**12.340**

The value of the criterion λ is calculated by the formula

$$\lambda = D_{max}\sqrt{\frac{n_1 n_2}{n_1+n_2}},$$

where $n_1 = n_2 = 75$ is the number of students in the control group (CG) and in the experimental group (EG). Under $n_{1,2} > 50$, the limit values are $\lambda_{0.01} = 1.63$, $D_{0.01} = 0.2662$; $\lambda_{0.05} = 1.36$, $D_{0.05} = 0.2221$.

The results of processing the experimental data are given in table 3 (before the formation stage of the pedagogical experiment) and in table 4 (after the formation stage of the pedagogical experiment).

The calculation of Kolmogorov-Smirnov's criterion before the formation stage of the pedagogical experiment results in $D_{max} = 0.08 < D_{0.05}$ and $\lambda = 0.4899 < \lambda_{0.05}$, which accepts the zero hypothesis H_0: $F(x) = G(x)$ with a significance level of 0.05.

After the formation stage of the pedagogical experiment, $D_{max} = 0.2667 > D_{0.05}$ ($D_{max} \approx D_{0.01}$) and $\lambda = 1.6330 > \lambda_{0.05}$ ($\lambda \approx \lambda_{0.01}$) allows the rejection of the zero hypothesis H_0 with a significance level of 0.05 and the acceptance of H_1: $F(x) \neq G(x)$.

Considering the fact that in the experimental groups, environmental competence is formed by the developed methods, one can state that this allowed better results. Therefore, we assume that the suggested hypothesis is experimentally confirmed.

The significance of changes in certain components of the environmental competence in the case of applying geoinformation technologies is determined by Fischer angular transformation (table 5) on the basis of table 2.

The statistic hypotheses are formulated as follows:

- H_0^i: the fraction of students with the i-th component of environmental competence ($i = 1,2,3,4,5$) at sufficient and high levels in the experimental groups was not greater than in the control;
- H_1^i: the fraction of students with the i-th component of environmental competence ($i = 1,2,3,4,5$) at sufficient and high levels in the experimental groups was greater than in the control.

Table 5 reveals that statistically significant changes did not occur when forming two components of the environmental competence: the second and the third ones. It is caused by the fact that the experimental work was conducted while teaching the special course, Environmental Geoinformatics, which was preceded by the course "Ecology" according to the model of applying geoinformation technologies when creating a future mining engineer's environmental competence. When studying the latter, statistically significant changes in the formation level of the second and the third components of the environmental competence were observed.

After the completion of the experimental work, the first component of environmental competence is the most developed, which is explained by the general orientation of mining and geological activity in sustainable industrial development. The fourth and the fifth components of environmental competence re-

Table 3: Calculation of the Kolmogorov-Smirnov's criterion before the formation stage of the pedagogical experiment.

Level	Absolute frequency		Accumulated frequency		Relative accumulated frequency		D
	CG	EG	CG	EG	CG	EG	
0 – low	35	41	35	41	0.4667	0.5467	0.08
1 – medium	31	23	66	64	0.88	0.8533	0.0267
2 – sufficient	9	10	75	74	1	0.9867	0.0133
3 – high	0	1	75	75	1	1	0
D_{max}							**0.08**
λ							**0.4899**

Table 4: Calculation of the Kolmogorov-Smirnov's criterion after the formation stage of the pedagogical experiment.

Level	Absolute frequency		Accumulated frequency		Relative accumulated frequency		D
	CG	EG	CG	EG	CG	EG	
0 – low	23	13	23	13	0.3067	0.1733	0.1333
1 – medium	27	27	60	40	0.8	0.5333	0.2667
2 – sufficient	15	28	75	68	1	0.9067	0.0933
3 – high	0	7	75	75	1	1	0
D_{max}							**0.2667**
λ							**1.6330**

Table 5: The ϕ^*-criterion value for each of the environmental competence components after the formation stage of the pedagogical experiment.

Environmental competence component	ϕ^*	Hypothesis (p)
Understanding and perception of ethical norms of behavior with regard to other people and nature (principles of bioethics)	3.212	$H_1^1(0.01)$
Environmental literacy	0.680	$H_0^2(0.05)$
A basic knowledge of ecology to be applied in one's professional activities	0.818	$H_0^3(0.05)$
The ability to apply scientific laws and methods to assess the condition of the environment, take part in environmental operations, perform an environmental analysis of steps in the field of activity, and to work out plans to reduce technogenic pressure on the environment	4.180	$H_1^4(0.01)$
The ability to ensure sustainable activities, and methods for the rational and complex development of georesources	3.250	$H_1^5(0.01)$

mained underdeveloped at a high level. This is due to the fact that the experimental special course had been suggested much earlier than the special professional subjects aimed at applying scientific laws and methods when assessing the condition of the environment, taking part in environmental operations, conducting an environmental analysis, working out plans to reduce the technogenic pressure of the industry on the environment, ensuring sustainable activities, and mastering methods to facilitate the rational and complex development of georesources.

In spite of this, the statistical significance of changes in the formation of the fourth and fifth components of environmental competence indicates that it is the introduction of professionally-oriented geoinformation technologies (mining and environmental GIS) in the process of training future mining engineers that predetermines the efficiency of the experimental work.

We can draw the conclusion that the application of mining and environmental geoinformation technologies is the major factor when forming environmental competence and their methodologically substantiated application is one of the conditions of training an environmentally competent mining engineer. Therefore, the research hypothesis is confirmed.

The analysis of the experimental work results concluded that the introduction of geoinformation technologies when training future mining engineers created the following conditions:

- sharing information in professional training through the systematic application of geoinformation ICT;
- increasing inter-subject connections between fundamental and professionally-oriented subjects through the integrated content when teaching Environmental Geoinformatics;
- using the research-based approach in training and teaching Environmental Geoinformatics; this is forms organization skills and allows individual and collective investigations to be conducted.

5 CONCLUSIONS

Applying geoinformation technologies to create a future mining engineer's environmental competence requires a system of interrelated methods and teaching methods to realize these technologies at all stages of creating competence. the authors have analyzed sources that investigate the problems of environmental competence formation and the of geoinformation technologies in training. this research also improves the system of competences and examines the geoinformation technology used in the education process.

The experimental research program aims to check 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 formation stage of the pedagogical experiment introduced the application of geoinformation technologies to create environmental competence in the special course, 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 methodological complex, "EcoKryvbas". After completing the experimental training, it was found that 49.33% of students in the control groups achieved a medium level of environmental competence maturity. 20% achieved a sufficient level, while in the experimental, 37.33% achieved a suffucuent level and 36% a medium level.

The pedagogical experiment results were processed and efficiency of the developed methods of training mining students was assessed using mathematical statistics. As the research aimed to determine differences in feature distribution (the level of maturity of the environmental competence) when comparing two empirical distributions (students of the control and the experimental groups) (Sidorenko, 2003, p. 34), the Pearson's χ^2-criterion or the Kolmogorov-Smirnov's λ-criterion and ϕ^*-criterion (Fischer's angular transformation) were used.

When using the ϕ^*-criterion, it was found that after the formation stage of the pedagogical experiment, students in both the control and experimental groups had statistically significant differences with regard to their achievement of sufficient and high levels of environmental competence maturity ($\phi^*_{emp} = 3.532 > 2.31 = \phi^*_{0.01}$). The adequacy of differences in the experimental and control groups was 0.99.

The χ^2-criterion was used to calculate the control and experimental samples after the formation stage of the pedagogical experiment revealed that $\chi^2 = 12.340 > 9.210 = \chi^2_{0.01}$ with the adequacy of differences in the experimental and control groups of 0.99 for the 3-level scale. Considering that intervals with zero frequencies were not acceptable and not less than 80% of frequencies were to be more than 5, the levels "sufficient" and "high" were united.

To find the level, on which the differences were the greatest, the samples of the formation stage of the pedagogical experiment were checked by means of the Kolmogorov-Smirnov's λ-criterion. The criterion value, $\lambda = 1.6330 > 1.36 = \lambda_{0.05}$, resulted in the students' differences in the experimental and control groups of 0.95 and $D_{max} = 0.08$, which corresponded to the maximum changes on the low maturity level of environmental competence.

The significance of the changes in environmental competence when applying geoinformation technologies was determined by means of the Fischer's angular transformation. It was found that statistically significant changes did not occur in the formation of the second ($\phi^*_{emp} = 0.680 < 1.64 = \phi^*_{0.05}$) and the third ($\phi^*_{emp} = 0.818$) ($\phi^*_{emp} = 0.818$) components of environmental competence. This was explained by the fact that the second stage of environmental competence formation (the special course, Environmental Geoinformatics) was preceded by the first stage (the special course, "Ecology"), during which the given components were formed. The changes in the rest of the environmental competence components were statistically significant: the first component $\phi^*_{emp} = 3.212$, the fourth component $\phi^*_{emp} = 4.180$, the fifth component $\phi^*_{emp} = 3.250$. The fourth and the fifth components of environmental competence remained underdeveloped due to this fact, and determined the need to conduct the third stage of environmental competence formation. The statistical significance of changes during the formation of the two components indicated that the introduction of profession-oriented geoinformation technologies (mining and environmental GIS) conditioned the efficiency of the experimental research work and its results confirmed the research hypothesis.

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