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INVESTIGATION OF THE PROCESSES OF THE INFORMATION TECHNOLOGIES INTEGRATION INTO THE TRAINING OF SPECIALISTS AT MINE RESCUE DEPARTMENTS

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ДОСЛІДЖЕННЯ ІНТЕГРАЦІЙНИХ ПРОЦЕСІВ ЗАПРОВАДЖЕННЯ ІТ-ТЕХНОЛОГІЙ ПІДГОТОВКИ ФАХІВЦІВ ГІРНИЧОРЯТУВАЛЬНИХ ПІДРОЗДІЛІВ

Purpose. The investigation of the education quality improvement achieved as a result of the introduction of information technology into the practical training of rescue workers.

Methodology. The experimental studies were conducted on the basis of a full factorial experiment. The results were processed using methods of mathematical statistics and regression analysis.

Findings. We have obtained the models determining the impact of the IT-based educational methods, which were introduced in combination with the traditional methods, on the quality of the rescuers training. The obtained models have proved the effectiveness of the rescuers training that was based on the use of the innovations together with traditional technologies.

Originality. For the first time we have obtained the mathematical models that determine the ratio of IT-based practical exercises and real equipment, and take into account the intellectual potential of students. The models allow determining the efficiency of the information technology that was integrated into the rescuers' practical training process.

Practical value. The obtained models are intended to determine the effectiveness of the IT-based training of rescuers during its integration into the educational process. The obtained models are being considered the first step in the development of intelligent algorithm of decision support in the implementation of different information technologies for training future rescue workers. The results have been introduced in the educational process of the Lviv State University of Life Safety, the network of educational Centers of Civil Protection and Life Safety, and the Main School of Fire Service in Poland. The results have been realized in the form of electronic applications to three specialized course books. One of them is recommended by the Ministry of Education and Science of Ukraine.

Keywords: *information technology, integration processes, rescuer, training*

Introduction. Since the development of Ukrainian educational system is oriented on integration with the European, it requires adaptation of its processes to functioning in the environment of a developed economy, in which the quality of educational product determines the relevance of an educational institution at the educational market. The world's practice proves that investments into the educational sphere contribute to the future potential of the society and indicate a high economic and social level of the country. Unfortunately, current social

and economic situation in Ukraine is difficult and causes global resource constraint of educational processes. In such conditions the problem of maintenance of the existing process of European integration of educational institutions becomes urgent. The rise of national educational institutions in the European educational medium is affected by the dynamic economic situation and requires an innovative approach and introduction of cutting-edge information technologies.

The conflicts that appear in the educational environment of Ukrainian institutions are caused by the forced necessity to maintain quality with dwindling resources.

The quality of education is linearly proportional to the resources available. In the situation of lack of resources, the institutions look for all possible ways to prevent the educational quality degradation. However, minimization of the resources (time, teaching staff, materials, etc.) naturally results in slow degradation of national education. The institutions with specific terms of study under the State Emergency Service of Ukraine (SESU) are not an exception. It is clear that there must not be any compromises concerning the quality-to-price ratio in the training of future rescue workers. But the economy dictates its terms, and there appears the necessity to develop innovative fundamentally different technologies of training of future rescue workers, including mine rescue teams.

Analysis of recent researches and publications. Many domestic scientists contributed to the theory and practice of development of modern IT-based educational techniques. The paper which was written by Yu. Rak, V. Skakun, O. Zachko, and T. Rak [1], the authors explored the ways of development of the educational environment and enhancement of the rescue workers' professional training using IT. The papers of N. Burak, and Yu. Rak [2, 3] described the study of the educational medium for the training of future rescuers in an IT turbulent environment. The models of mental space and informational educational environment for rescuers' training were the main result of the studies.

The problems of development and implementation of IT in the educational sphere with the aim of training of the specialists with civil professions was also studied comprehensively. For instance, the Scientific Bulletin of National Mining University has published several papers that cover the matter under investigation. The paper of Rizun, N. [4] solves the problem of the quality improvement of the training process of students who learn Economic Cybernetics through the development and introduction of the system of diagnostics and control over the quality of study in a higher educational institution. The system is based on the complex use of four fundamentally-new criteria. In the subsequent paper [5] the author solves the problem of the increase of the accuracy and validity of the methods of diagnostics of the quality of education through the minimization of the uncertainty in measurements made in the systems of man-machine interaction.

The unsolved aspects of the problem. We have a never-ending list of achievements in solving of educational problems using IT. However, the number of such works that are focused on the rescue workers' training is quite small. As a rule, the scientific tasks are being solved through development and introduction of the IT-based methods and study of their efficiency paying no regard to traditional means and technologies, which were obtained through years of work. Taking into consideration of the peculiarities of the training process in the institutions with specific conditions of the study, namely the ministerial educational institutions of SESU [6, 7], the innovative technologies should be interchanged with traditional methods of practical training. This is reasoned by the fact that future rescue workers will use their

professional skills in extreme conditions. That is why the rescue equipment handling must be practiced until it becomes automatic. The problem of the blatant disregard of traditional methods of training during the introduction of IT-based innovative educational methods remained unsolved.

Task. Considering the unsolved aspects of the problem described, we set the main task of the research is to explore the processes of integration of the information technology into the practical training of future rescue workers and to determine the pattern of change of the education quality achieved as a result of its implementation. Concerning the scale of the set task and its labor intensity, the paper describes one of the most complicated processes of combining traditional and innovative methods of training, the acquirement of skills of handling the water pump of a fire engine and rescue vehicle.

Results. Some results obtained in the previous researches of the problem served as the base for the algorithm of selection of separate phases of educational projects to be included in a comprehensive educational program [8]. However, the process of approbation of the main results revealed slight deflection from theoretical studies, which led to further work on verification of the adequacy of the developed models and the validity of the results obtained. This work was aimed at the improvement of the efficiency of integration processes of the introduction of IT into the practical training of rescuers.

The influence of a combination of the IT-based and traditional technologies of the students' training was studied by the method of the 2^3 -type full factorial experiment. This type of experiment allowed us to determine the value of the regression relationship between the expected education quality (M), number of the practical trainings of a certain exercise using the IT methods (T) and real equipment (H), and the intellectual potential of a student who uses the combined technology of training (M_p), which is defined by the academic performance in the previous years.

The methodology of the experimental research and its results were described in the previous publications as well as the parameters of regression relationship and their border values. However, some of the basic output values are presented in Tables 1, 2 for illustration purposes.

Table 1 shows the results of coding the factors through the converting them into non-dimensional values since the parameters of the regression relationship have different dimensions.

Using the methodology of the full factorial experiment, we have built the design matrix of the research,

Table 1

Limit values of the parameters and their dimensions

Factor Level	H , times		T , times		M_p , points	
	$\tilde{X}_1 = H$	$\ln \tilde{X}_1$	$\tilde{X}_2 = T$	$\ln \tilde{X}_2$	$\tilde{X}_3 = M_p$	$\ln \tilde{X}_3$
Higher	6	1.792	6	1.792	91.380	4.515
Lower	2	0.693	2	0.693	50.654	3.925

Table 2

Design matrix of the experimental research and values of the parameters under review

Experiment No.	Factors						M_{mean} , points
	X_1		X_2		X_3		
	Code	H	Code	T	Code	M_p	
1	-1	2	-1	2	-1	50.65	70.45
2	+1	6	-1	2	-1	50.65	78.3
3	-1	2	+1	6	-1	50.65	77.1
4	+1	6	+1	6	-1	50.65	89.6
5	-1	2	-1	2	+1	91.38	70.77
6	+1	6	-1	2	+1	91.38	80.14
7	-1	2	+1	6	+1	91.38	74.14
8	+1	6	+1	6	+1	91.38	94.86

according to which we have carried out the preliminary experiments and obtained the relevant values of the parameter M .

The regression relationship between the values H , T , M_p and M can be expressed by different response functions. The difference between the variants of expression consists in the way the independent variable X_n is given and in the coefficients of the regression equation. Depending on the obstacles the utilization of a particular function will give a more unbiased result.

That is why, to prove the validity of the predicted results, we executed the log-log, log-linear, linear-log, and linear-linear response functions in sequence.

First, taking into account that the determined factors that influence the educational process belong to different dimensions, we executed the log-log function.

To fulfill the task at hand, the independent variables \tilde{X}_i were given as non-dimensional values (log-log, log-linear execution) by the formula

$$X'_i = \frac{2 \cdot (\ln \tilde{X}_i - \ln \tilde{X}_{i\max})}{\ln \tilde{X}_{i\max} - \ln \tilde{X}_{i\min}} + 1.$$

In the case when the independent variables \tilde{X}_i were given as actual values (linear-log, linear-linear response functions), the following formula was used

$$X_i = \frac{2X_i - X_{i\max} - X_{i\min}}{X_{i\max} - X_{i\min}}.$$

Let us formulate the logarithmic response function that describes the dependence of the predicted value of the education quality parameter upon three independent factors H , T and M_p with coded variables, which take into account the mutual influence of the factors, as follows

$$\ln M = b'_0 + b'_1 X'_1 + b'_2 X'_2 + b'_3 X'_3 + b'_{12} X'_1 X'_2 + b'_{13} X'_1 X'_3 + b'_{23} X'_2 X'_3 + b'_{123} X'_1 X'_2 X'_3. \quad (1)$$

The linear model (1) does not require taking the logarithm of the coefficients b_n and the independent variables X_i . Consequently, the log-linear model does not require taking the logarithm of the coefficients b_n . The linear-log model is realized without taking the logarithm of the independent variables X_i .

The following dependencies allow us to calculate the coefficients b'_n and b_n taking into account X_{in} , which is the code of n -th factor and i -th experiment, the mean value of the result of i -th experiment under certain values of the factors M_i and the number of the experiments N

$$b'_n = \frac{1}{N} \sum_{i=1}^N X_{in} \ln \bar{M}_i; \quad b_n = \frac{1}{N} \sum_{i=1}^N X_{in} \bar{M}_i.$$

With the equal number of replicated experiments r ($r = 2$) at each stage of the combination of factors' levels, the consistency of the results was verified by the Cochran's Q test. The test considers the ratio of the maximum value of the dispersion of scattering to the value of the error mean square. The comparison of the calculated value and the critical value has proved the hypothesis of the homogeneity of variance since $G = 0.214 < G_{cr} = 0.68$.

Student's t-test was employed to evaluate the relevance of the regression coefficients b'_n . The results showed that some of the coefficients are irrelevant. However, the model that involves only relevant coefficients does not take into account all the values of independent factors, which influence the education quality. That is why we considered all the coefficients when switched to the model with actual values.

As the next step, we verified the adequacy of the model by F -test. The comparison of the calculated value and the critical value proves that the model (1) is adequate, since $F = 1.28 < F_{cr} = 3.69$.

To determine the accuracy of the expression of the experimental data by the regression equation, we calculated the multiple correlation coefficient $R = 0.96$. Based on this we can state that the log-log response function almost wholly describes the results of the experimental study.

To switch to the model with actual values, we inserted the transform of the independent variables \tilde{X}_i into the model (1) taking into account the regression coefficients b'_n . Through the processing of the experimental results by the regression analysis, we obtained the dependency in the form of log-log function. It allows determining the expected education quality of the future rescuers who study by the combined training technology. The obtained dependence makes it possible to get an idea of the regularities of the education quality change gained as a result of the implementation of the IT-based methods in combination with traditional methods of training; it can be expressed as follows

$$M = \exp(3.817 + 0.25 \cdot \ln H + 0.611 \cdot \ln T + 0.084 \cdot \ln M_p - 0.387 \cdot \ln H \cdot \ln T - 0.045 \cdot \ln H \cdot \ln M_p - 0.141 \cdot \ln T \cdot \ln M_p + 0.108 \cdot \ln H \cdot \ln T \cdot \ln M_p), \quad (2)$$

where, H is the number of exercises with application of the real equipment, T is the number of exercises with

application of IT, and M_p is the level of the intellectual potential of a student.

Using the obtained model we have simulated the index of the practical training quality, when the combined technology was applied in different ways (Fig. 1).

Then, in order to verify the accuracy of the results obtained with the help of the log-log response function in the form of the model (2), we determined the corresponding education quality parameters using the equations set up in different ways. The log-linear response function expressed the relationship between the parameters under review as follows

$$M = 36.02 + 20.64 \cdot \ln H + 48.67 \cdot \ln T + 6.9 \cdot \ln M_p - 32.71 \cdot \ln H \cdot \ln T - 4.13 \cdot \ln H \cdot \ln M_p - 11.53 \cdot \ln T \cdot \ln M_p + 9.31 \cdot \ln H \cdot \ln T \cdot \ln M_p. \quad (3)$$

Using the obtained dependence we simulated the education quality parameter with different ways of execution of practical exercises in combination (Fig. 2).

Next, we obtained the linear-log response function, which has the following view

$$M = \exp \left(4.369 + 0.078 \cdot \left(\frac{H}{2} - 2 \right) + 0.054 \cdot \left(\frac{T}{2} - 2 \right) + 0.005 \cdot \left(\frac{M_p}{20.363} - 3.488 \right) + 0.02 \cdot \left(\frac{H}{2} - 2 \right) \cdot \left(\frac{T}{2} - 2 \right) + 0.014 \cdot \left(\frac{H}{2} - 2 \right) \cdot \left(\frac{M_p}{20.363} - 3.488 \right) - 0.001 \cdot \left(\frac{T}{2} - 2 \right) \cdot \left(\frac{M_p}{20.363} - 3.488 \right) + 0.009 \cdot \left(\frac{H}{2} - 2 \right) \cdot \left(\frac{T}{2} - 2 \right) \cdot \left(\frac{M_p}{20.363} - 3.488 \right) \right). \quad (4)$$

Using the model (4), we determined the expected value of the education quality, when the combined technology was applied in different ways (Fig. 3).

At last, we obtained the model describing the relationship between the parameters H , T and M_p as a linear-linear response function

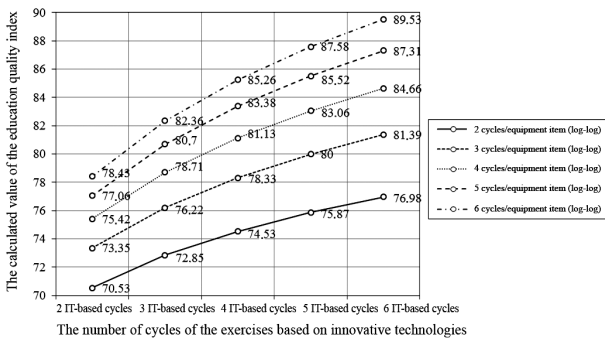


Fig. 1. The dependence of the education quality on the values of the factors H and T when M_p is a constant (51 points) (log-log model)

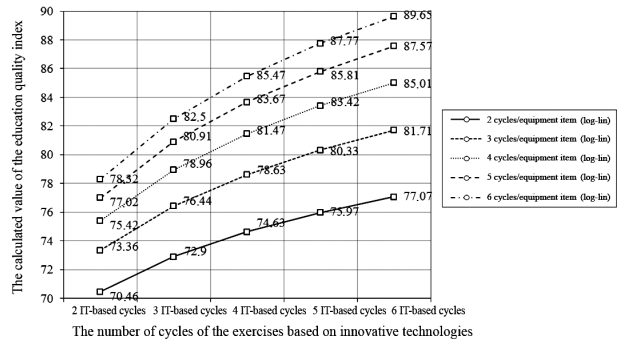


Fig. 2. The dependence of the education quality on the values of the factors H and T when M_p is a constant (51 points) (log-linear model)

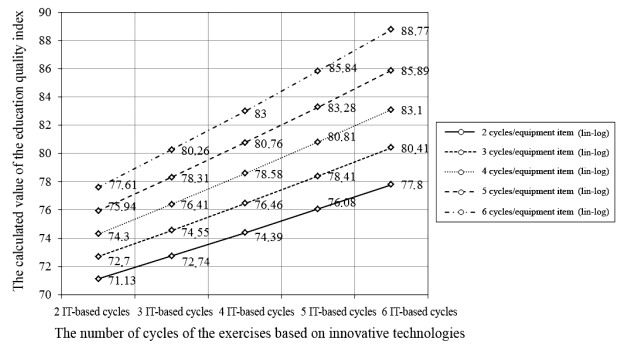


Fig. 3. The dependence of the education quality on the values of the factors H and T when M_p is a constant (51 points) (linear-log model)

$$M = 79.412 + 6.297 \cdot \left(\frac{H}{2} - 2 \right) + 4.497 \cdot \left(\frac{T}{2} - 2 \right) + 0.55 \cdot \left(\frac{M_p}{20.363} - 3.488 \right) + 1.992 \cdot \left(\frac{H}{2} - 2 \right) \cdot \left(\frac{T}{2} - 2 \right) + 1.21 \cdot \left(\frac{H}{2} - 2 \right) \cdot \left(\frac{M_p}{20.363} - 3.488 \right) + 0.01 \cdot \left(\frac{T}{2} - 2 \right) \cdot \left(\frac{M_p}{20.363} - 3.488 \right) + 0.83 \cdot \left(\frac{H}{2} - 2 \right) \cdot \left(\frac{T}{2} - 2 \right) \cdot \left(\frac{M_p}{20.363} - 3.488 \right). \quad (5)$$

Using the model (5), we determined the expected value of the education quality, when the combined technology was applied in different ways (Fig. 4).

To use the models (2–5) for prediction of the knowledge and skills of future rescuers, we should assign the number of cycles of exercises with real equipment and the IT-based, and take into account the level of student's intellectual potential.

The dependency diagrams (Fig. 1–4) sum up the combined methodology of formation of the professional competence of rescuers using traditional and IT-based training methods. The expected quality increases with the increase of the number cycles of practical exercises.

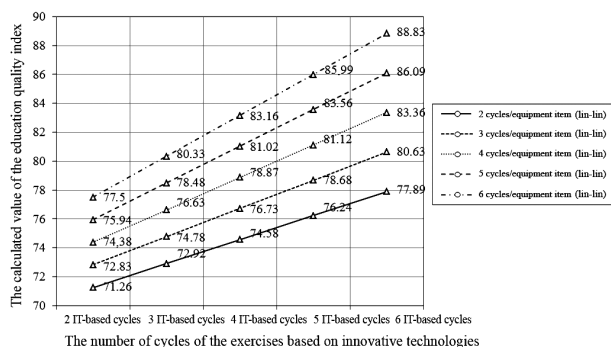


Fig. 4. The dependence of the education quality on the values of the factors H and T when M_p is a constant (51 points) (linear-linear model)

Consequently, when there is a restraint for the educational process expenditures the introduction of the technology of combined training appears an option for maintenance of the education quality.

The comparison of the received results (Fig. 1–4) showed that the maximum scattering of the expected quality parameters obtained by different models does not exceed 3%. Thus, the verification of the adequacy of the log-log model by F -test proves the relevance of all the others.

Conclusion. Based on the results obtained we may conclude that:

1. The analysis of the processes of integration of the IT into the educational process revealed the problem of the blatant disregard of traditional training methods, which is unacceptable in many spheres, namely in rescuers' training.

2. Using the experimental models, we have proved the efficiency of the combined method of rescuers' practical training which implies a combination of the IT-based and traditional techniques. The models received are the first step in the development of the decision support algorithm for the process of integration of IT into the training of rescue workers.

The results have been introduced in the educational process of the Lviv State University of Life Safety, the network of educational Centers of Civil Protection and Life Safety, and the Main School of Fire Service in Poland (Warsaw).

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Meta. Дослідження закономірностей зміни якості освітніх процесів у результаті запроваджен-

ня інноваційних ІТ-технологій для практичної підготовки майбутніх фахівців рятувальної сфери.

Методика. Експериментальні дослідження проводились на основі методу повнофакторного експерименту. Оброблення результатів проведене з використанням методів математичної статистики та регресійного аналізу.

Результати. Одержані моделі визначення впливу запроваджених ІТ-освітніх технологій на якість підготовки рятувальників за умови різних обсягів застосування та поєднання із класичними методами навчання. За допомогою одержаних моделей доведена гарантована ефективність комбінованого методу практичної підготовки рятувальників, заснованого на сумісному використанні інноваційних і класичних технологій.

Наукова новизна. Уперше одержані моделі, що враховують співвідношення параметрів кількості практичних відпрацювань визначеної вправи із залученням ІТ-технологій і реального устаткування, а також інтелектуального потенціалу студента та забезпечують можливість визначення ефективності інтеграційних процесів ІТ-технологій у системі практичної підготовки фахівців рятувальної сфери.

Практична значимість. Одержані в роботі моделі надають можливість визначати ефективність розроблених інформаційних технологій підготовки рятувальників у процесі їх інтеграції в досліджуване освітнє середовище та є першим кроком у розробленні комплексного алгоритму інтелектуальної підтримки прийняття рішень під час реалізації інтеграційних процесів запровадження будь-яких ІТ-технологій для підготовки майбутніх фахівців рятувальних підрозділів. Результати роботи впроваджені в навчальний процес Львівського державного університету безпеки життєдіяльності, мережі навчальних пунктів навчально-методичних центрів цивільного захисту та безпеки життєдіяльності, Головної школи пожежної служби Республіки Польща (м. Варшава). Розроблені інформаційні технології увійшли у вигляді електронних додатків до трьох спеціалізованих навчальних видань, одне з яких одержало рекомендацію Міністерства освіти і науки України.

Ключові слова: *інформаційні технології, інтеграційні процеси, підготовка рятувальника*

Цель. Исследование закономерностей изменения качества образовательных процессов в результате внедрения инновационных ИТ-технологий

для практической подготовки будущих специалистов спасательной сферы.

Методика. Экспериментальные исследования проводились на основе метода полнофакторного эксперимента. Обработка результатов проведена с использованием методов математической статистики и регрессионного анализа.

Результаты. Получены модели для определения влияния внедренных ИТ-образовательных технологий на качество подготовки спасателей при различных объемах применения и сочетании с классическими методами обучения. С помощью полученных моделей доказана гарантированная эффективность комбинированного метода практической подготовки спасателей, основанного на совместном использовании современных инновационных и классических технологий.

Научная новизна. Впервые получены модели, которые учитывают соотношение параметров количества практических отработок определенного упражнения с привлечением ИТ-технологий и реального оборудования, а также интеллектуального потенциала студента и обеспечивают возможность определения эффективности интегрированных информационных технологий в процессе практической подготовки специалистов спасательной сферы.

Практическая значимость. Полученные в работе модели предназначены для определения эффективности разработанных информационных технологий обучения в процессе их интеграции. Модели являются первым шагом в разработке алгоритма интеллектуальной поддержки принятия решений при реализации интеграционных процессов внедрения любых ИТ-технологий для подготовки будущих специалистов спасательных подразделений. Результаты работы внедрены в учебный процесс Львовского государственного университета безопасности жизнедеятельности, сети учебных пунктов учебно-методических центров гражданской защиты и безопасности жизнедеятельности, Главной школы пожарной службы Республики Польша (г. Варшава). Разработанные информационные технологии вошли в виде электронных приложений в три специализированные учебные издания, одно из которых получило рекомендацию Министерства образования и науки Украины.

Ключевые слова: *информационные технологии, интеграционные процессы, подготовка спасателя*

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