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Integrative Module Technology of Future Engineers Training in the Field of Ecological-Economic Safety

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ABSTRACT

The paper relevance is conditioned by the society and the state need to train the specialists who are ready to work in conditions of high ecological production risks. The paper purpose is to develop and justify the system on forming the technical universities graduates' professional competence in the field of environmental and economic safety on the basis of integrative-modular learning technology's implementation. The authors presented a structural and functional model for integrating the future specialists' training content in the field of environmental and economic safety. The research's leading approach is a systematic approach that allows considering the future specialists' professional competence forming process in the field of environmental and economic safety on the basis of integrative-modular technology. The authors develop a criteria-leveled component aimed at revealing the level of the professional competence formation in the field of environmental and economic safety. The system diagnostics containing the necessary set for criteria allowing estimating the level of graduates' professional competence formation in the sphere of ecological and economic safety is presented. The paper is intended for researchers, practitioners, enterprises managers involved in the issues on environmental and economic production activities and engineers' vocational training.

Keywords: ecological and economic safety, professional competence formation, specialists training, integrative-modular technology, educational organizations, system diagnostics

INTRODUCTION

One of the training priority tasks in higher technical educational institutions is the graduates' preparation as broad profile specialists intended for independent engineering, research, management and organizational activities in the life safety sphere [1]. Formation necessary professional knowledge, skills and functional qualities necessary for the graduate is a key element in solving the task on training qualified specialists on techno-sphere safety capable of directing the team and professionally solving production tasks. Based on the scientific and pedagogical literature analysis [2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13] an objective need is defined to build a qualitatively another educational system, with the priority of new psycho-pedagogical and production technologies, new norms for professional activity and rules for people behavior, based on universal values. The integrative approach application becomes

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more and more priority direction in the university's special vocational training for specialists in the engineering and technical field, which with the engineers professional training in techno-sphere safety implies: identifying interdisciplinary links of academic disciplines, identifying integrative constants in their content, taking into account the future specialists' profile specialization; the formation on this basis the system engineering thinking, professional competence and readiness for professional activity.

However, with all the scientific and practical importance of the research conducted in this field, it should be noted that the study of system-forming factors' influence on the technology for designing the special disciplines' content in the context of integrative-modular training with a focus on the competitive specialists' training was not the main goal [14, 15, 16, 17, 18, 19].

Such a vision requires new solutions both in the educational process organization in general, and in the disciplines content designing technology in particular. And in this sense, the most perspective one is considered the integrative-modular learning technology, which in the traditional educational system is not given special attention.

MATERIALS AND METHODS

Investigating the notions "danger" and "safety" [20] as ecological and economic system's important characteristics, we identified potential sources for environmental and economic danger (military, economic and social, environmental threats and threats of terrorism) and revealed that the danger is understood as the possibility of a negative event onset, and *the ecological and economic danger* is the object of security activity. Safety means state of protection of the individual's, society's and the state's vital interests from internal and external threats [21, 22, 23, 24]. In this vein, we introduced a definition for *environmental and economic safety,* which should be understood as a *number of conditions under which the restriction or elimination of any factor or process harmful effect occur (natural, economic, techno-gene, anthropogenic, etc.) on a person's, society's and the state's physical and spiritual health state.*

The contradictions aggravation between the specialists' professional activities integrative nature in the "Techno-sphere Safety" and the training discrete-disciplinary system in special educational organizations created the need for integration processes in the education [25], in her studies defines integration as a developmental side, connected with the unification of once disparate parts: it is a kind of reaction to the processes from the bifurcation of a single, occurring in all spheres of being and cognition. The knowledge integration at the present stage is distinguished by a qualitatively different nature in comparison with the previous development: connections cover not only methods, but also concepts, theories and the very style of scientific thinking.

According to the authors team, integration makes it possible to move from disciplines' local and isolated study to their interrelated and complementary, integrated study. In study tasks view, a set of pedagogical conditions for the disciplines' and special knowledge's integration in the system of vocational training for future engineers in techno-sphere safety was determined and justified, and a specialist model was developed (**Figure 1**).

The specialist model is considered as the most complete description of the specialist's activity in terms of its correspondence to the vocational training objectives in the field of environmental and economic safety. The basis for building the model is the activity -based approach and the principle of modular training [26, 27, 28]. The following elements are included in the engineer's model in the techno-sphere safety: the qualification characteristic, which describes what a specialist should know and be able to do, characteristics for intellectual qualities and person's social properties [29, 30]. Thus, the engineers' qualities in a techno-sphere safety reflect the purpose of their professional training. We also believe that this model should necessarily include elements reflecting the future specialists' components of professional competence and their readiness [31].

Analyzing modern approaches to the concept content of "professional competence" we have identified the structure of professional competence for the techno-sphere safety specialist in the field of environmental and economic security (**Table 1**).

The authors determined that the formation of integrated special courses should be subordinated to the following: the integrated course stem should be based on the systemic and integrative approach principles, the material specificity being studied is taken into account; it is necessary to use the system of course integrative module education, where *the first module* is responsible for forming the educational core on integrated disciplines' fundamental laws basis, *the second* - for the formation of ecological and economic knowledge, skills and functional qualities foundations, providing safety activity, *the third* - for professional competence formation in the field of environmental and economic security and readiness for practical activities in their professional field; the integrated course's subject-content information should be oriented towards the formation of integral consciousness and thinking, key qualification qualities and competences, and the training specialization [14, 32, 33].

Value's potential
- Perception of human life and vital interests of society as the main value
- Actualization of the need for self-realization, aspiration for self-development and self-improvement
- Healthy lifestyle. Motivation for professional and managerial activities
- Understanding of the need and awareness role of training in the field of environmental and economic security

↕

Graduate Qualification Characteristics

Field of activity -Hazard Analysis and Identification; - Protection of man, nature, economic objects and the techno-sphere from hazards (fires, catastrophes, natural disasters and others), elimination of consequences of hazard exposure; -Expertise of safety, sustainability and ecological compatibility of technologies, technical facilities and projects.	**Objects of activity** - Human - Hazards connected with human activities and dangerous nature processes - Methods and means of protecting a person, nature and objects of the economy from hazards and harmful effects - Methods and means of evaluation of hazards, rules for rationing of hazards and anthropogenic impact on the habitat environment	**Kinds of activities** - Organizational - managerial - Operationally - service - Research - Design and constructional - Productionally-technological - Monitoring and diagnosis of vocational orientation, -Ecological and socio-vocational education

↕

Personal qualities -Vocationally significant psychophysiological, personal qualities - Vocationally significant social and personal qualities - Vocationally significant socio-cultural qualities -Vocationally necessary qualities of ecological consciousness	SPECIALIST IN THE FIELD OF ECOLOGICAL AND ECONOMIC SAFETY	**Key Qualifications** -Motivation to vocational activity and vocational direction -Enterprising and communicative nature - Technological skillfulness -Organizational and independent nature - Tolerance and empathy - Creative nature

↕

Professional competency and competence -Ecological and economic competence - Psychological competence - Socio-cultural competence - Information competence	**Readiness for vocational activity** - Motivational component - Orientation component -Psychophysiological component -Socio-psychological component - Socio-vocational component - The operational component - Reflective component

Figure 1. Model of a techno-sphere safety specialist who is competent in the field of environmental and economic safety

Table 1. Structure of the techno-sphere safety specialist's professional competence in the field of environmental and economic safety

Professional competence of the specialist of the state fire service (ministry of emergency situations in the Russian federation) in the field of ecological-economic safety	**Components of competency**
Ecological and economic competence	- General scientific - Ecological - Economic - Activity-deed based
Sociocultural competence	- Social - General-cultural - Component of ecological culture
Psychological competence	- Perceptive - Interactive
Information competency	- Content-informational - Analytical - Computer

The authors developed a structural and functional model for the process on integrating the training content of future techno-sphere security specialists in the field of environmental and economic security (**Figure 2**).

As it is shown in the figure, the integration system-forming factor is the training goals, in these objectives context, the tasks of training are determined, and these problems' solution is achieved by the integrated course's development. The modern understanding of the educational role in ensuring the society's sustainable development has predetermined the selection of integrated knowledge's subject areas: it is ecology, economics, dangerous fire factors forecasting, dangerous natural processes, technical systems reliability and techno-gene risk.

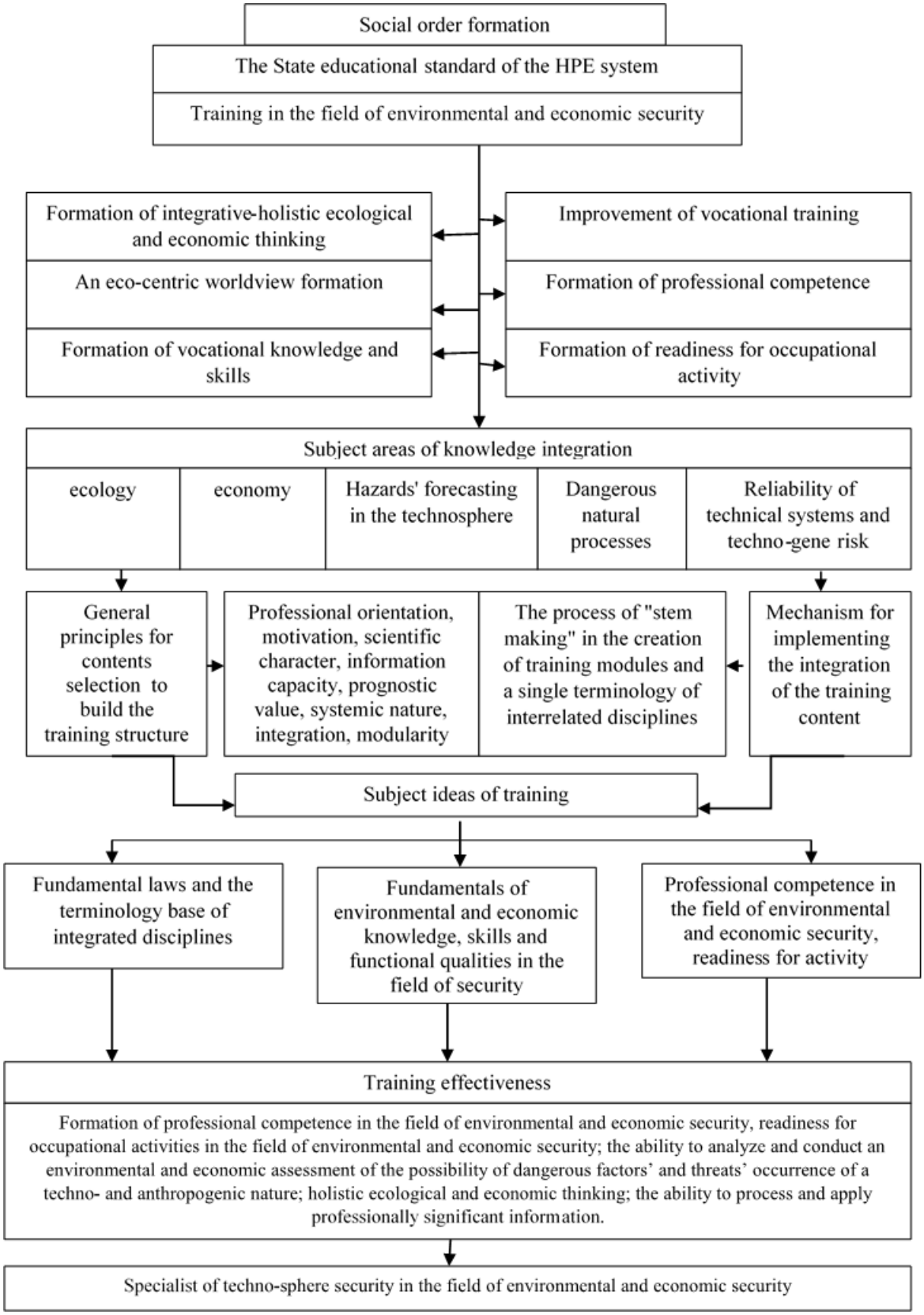

Figure 2. Structural and functional model for integrating the content of future specialists training in the field of environmental and economic safety

Table 2. Criteria-leveled scale for the formation of professional competence in conjunction with the professional competence's components (PC)

PC Components	Levels of PC formation								
	Reproductive (I)			Productive (II)			Creative (III)		
	Criteria for evaluation			Criteria for evaluation			Criteria for evaluation		
	PK	PS	FQ	PK	PS	FQ	PK	PS	FQ
Ecological and economic	1	2	3	13	14	15	25	26	27
Socio-cultural	4	5	6	16	17	18	28	29	30
Psychological	7	8	9	19	20	21	31	32	33
Informational	10	11	12	22	23	24	34	35	36

We have chosen a mechanism for the integration implementation, which is based on the knowledge "stem making" process, where the basis is ecology and the training modules creation.

Substantiating the integrated course content as an essential component of specialist's professional training, we can formulate the initial assumptions: the integrated knowledge assimilation creates the opportunity for the students to develop professional competence in the field of environmental and economic safety which is necessary for a modern specialist; in the learning process, students acquire knowledge, skills and functional qualities that are realized in their professional activities [34].

RESULTS

The idea of integrative module education is that, firstly, the training is built on individual functional units - *modules* that allow students to advance individually to a certain level in professional competence formation; secondly, it creates the basis for sustainable positive motives formation for future professional activity; in the third, involves the acquisition and assimilation of knowledge, skills and functional qualities on students personal inclusion in professional competence forming process. The goal of modular training is to provide the training flexibility, its adaptation to individual needs of the person, to the basic training level. The integrative-modular technology for forming professional competence in the field of environmental and economic safety used in our research, like any other, is impossible without a system diagnosis creation. Therefore, when creating a modular program, we took into account the availability of various types of control that allow us correctly to assess the level of professional competence formation in the field of environmental and economic safety.

At the *ascertaining stage* in experimental work, we developed and characterized the criteria-leveled component, which was used to determine the professional competence's formation level in the field of environmental and economic safety. As it was already noted above, professional competence in the field of environmental and economic safety is the future specialist's integrative characteristic; therefore, cognitive, operational and personal components can be the criteria for assessing competence, each of which is presented in the ecological-economic, psychological, socio-cultural and information aspects [35]. To confirm the proposed criteria validity for assessing professional competence, the expert evaluation method (Delphi method) was used, therefore, in accordance with the program of experimental research work, an expert group of five persons was formed (including candidates and doctors of pedagogical, economic and technical sciences). The score sheet and the rank matrix included 5 factors, each of which corresponded to some criterion: *functional qualities; professional motivation; value attitude to acquired knowledge, skills; professional knowledge; professional skills.* According to the data obtained from experts, the ranks matrix was compiled, on the basis of which the professional knowledge, professional skills and functional qualities of a techno-sphere safety specialist are recognized as criteria for assessing professional competence in the field of environmental and economic safety.

To convert qualitative indicators into quantitative indicators, the levels of professional competence formation in the field of environmental and economic safety were used in the study, namely *reproductive (I), productive (II), creative (III)* On the allocated characteristics basis of the levels of professional competence formation, a criteria-leveled scale of future specialists' professional competence formation in techno-sphere security in the sphere of environmental and economic safety was developed (**Table 2**), where figures from 1 to 36 determine independent characteristics of the criteria for professional competence's each component formation.

The specialized departments' practice in engineering universities (Kazan, Yekaterinburg, St. Petersburg, Rostov-on-Don) was analyzed and as the general research methods the generalized pedagogical experience in techno-sphere safety engineers' training for professional activities was used. The survey results showed that 87.6% of respondents (out of 27 respondents) recognize the need for training in the field of environmental and economic

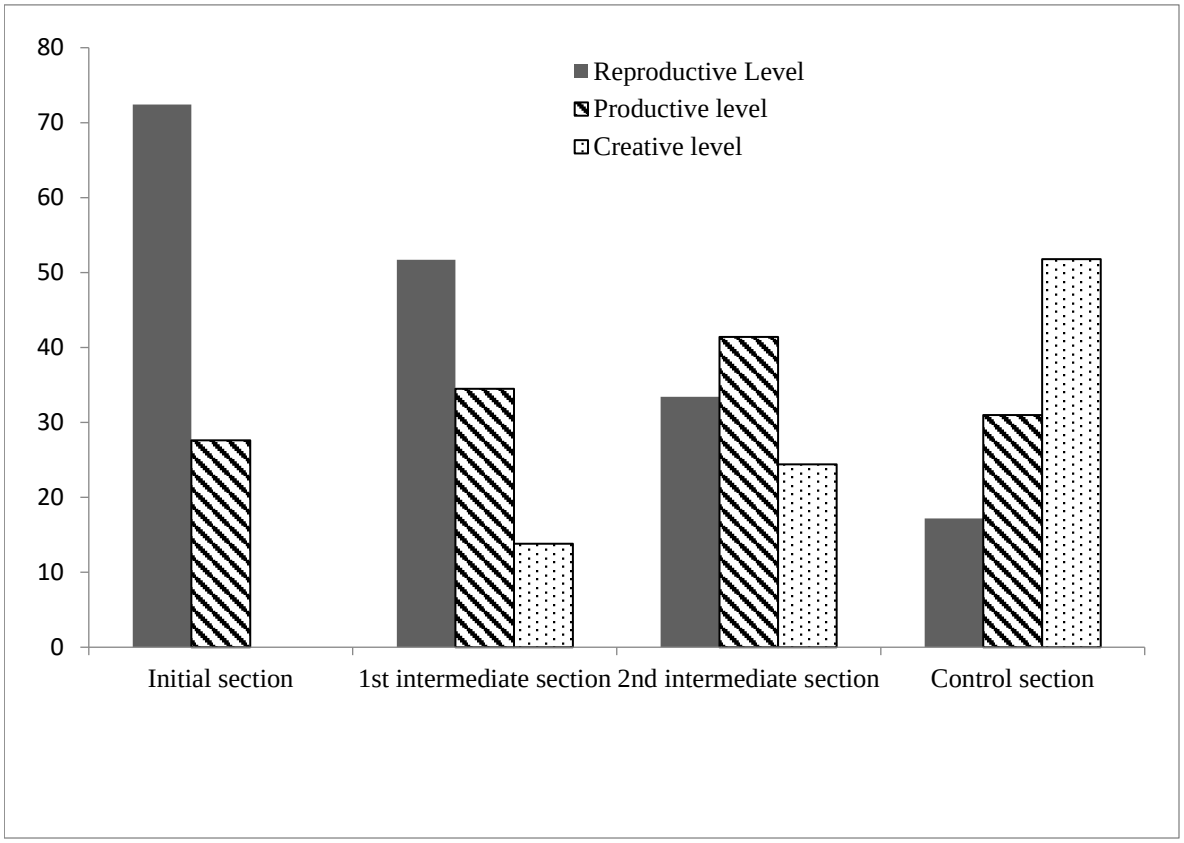

Figure 3. Growth dynamics in professional competencies' formation level

safety; 12.4% of respondents believe that the acquisition of knowledge for professional competence formation in this area is at the proper level and does not require the integration of separate interrelated disciplines.

The initial level of professional competence formation among future techno-sphere safety engineers showed that about 90% of the1st-year students, 85% of 2nd-year students and 70% of 3rd-year students have a reproductive level of professional competence, about 10% (1 course), 15% (2nd year) and 30% (3 years) - productive, students with a creative level were not identified.

The content of the forming phase in the experimental work was the approbation of the integrative special course "Ecological and economic safety in techno-sphere safety structure", within the framework of which the future Techno-sphere safety specialists' professional competence was formed in the field of environmental and economic safety, the experimental groups' monitoring and system diagnostics was carried out in the 3rd course (CG3 -1 - controlled, EG3 -1-experimental). To determine the effectiveness of students training in the field of environmental and economic safety (EES) and to reveal the dynamics in the professional competence formation level in the field of EES, intermediate and control sections presented in **Figure 3** were conducted in the control and experimental groups.

The results of the control section confirmed the presence of positive dynamics in the experimental group EG_3 - 1.

It should be noted that according to the control section results, positive changes in EG_3-1 take place according to all criteria for the formation of future engineers' professional competence in the field of environmental and economic safety and confirms the chosen direction's correctness in the pedagogical organization process. For quantitative proof and the results' objectivity of our study, the verification procedure of V.P. Bespal'ko [36] was used. Its essence is to calculate and compare the share of professional competence formation in the field of environmental and economic safety for each competence's structural component (**Table 3**).

Table 3. Assessment of the share of the formation of professional competence in the field of environmental and economic security

Competencies	Average value by group			Share of PC formation
	Professional values	Professional skills	Functional qualities	
Experimental group EG_3 -1.				
Ecological and economic	4,3	4,4	4,3	0,86
Socio-cultural	4,3	4,2	4,1	0,84
Psychological	4,3	4,4	4,2	0,86
Information	4,2	4,1	4,2	0,83
The control group CG_3 -1				
Ecological and economic	3,0	3,1	3,0	0,60
Socio-cultural	3,1	3,1	3,0	0,61
Psychological	3,4	3,3	3,3	0,66
Information	3,1	3,2	3,1	0,62

Table 4. Experimental value of the Piersen criterion CG_3 -1. EG_3 -1

№	Index	Groups	Level of formation			
			Reproductive	productive	Creative	T exp.
The ascertaining stage						
1. 1.	1 Professional competence in the field of EES	CG_3 -1.	20	10	0	
		EG_3 -1.	20	9	0	
			0.00	0,05	0,00	0,05
The final stage						
2.	Professional competence in the field of EES	CG_3 -1.	19	11	0	
		EG_3 -1.	5	11	13	
			8,20	0,00	13,00	21,20

Based on the obtained results, the dynamics in the level of competence formation among students in the experimental group is tracked, where a special course was tested on the basis of integrative-modular training technology. It should be noted that in the experimental group, some students did not have a positive dynamics in competencies formation. The approved special course was revised, the reproductive components of students' educational and professional activity were enlarged, taking into account the students gaps in the experimental group, and the share of professional competence's formation in the field of environmental and economic safety was re-evaluated, the result of which can be confirm its formation, since the data obtained exceed 70% threshold.

To carry out the analysis of the experimental data reliability, the Pearson test (x2) was used, which allowed to determine the null hypothesis: whether the differences between the data obtained in the ascertaining and control experiment stages in the control (CG3-1) and experimental (EG3-1) groups which go beyond the measurement error, whether the changes in the professional competence parameters' formation in the field of environmental and economic safety of future techno-sphere safety engineers random after the experimental work's final stage completion. At a 5% significance level and the of freedom degrees number equal to 2, the theoretical value of the Pearson Tteor coefficient is 6.00. **Table 4** shows the experimental values of the Pearson Texsp for the control and experimental groups at the ascertaining and final stage. Comparison of the control and experimental groups at the ascertaining stage shows that the value of Texsp much less than Tteor, i.e. the professional competence formation in the field of environmental and economic safety in both groups was the same, the sample is considered homogeneous.

Comparison of groups at the final stage shows that the value T_{exsp}- is significantly higher than T_{teor}. This suggests that in the experimental group, as a result of pedagogical influence, significant changes occurred in professional competence formation in the field of environmental and economic safety in comparison with the control group. Changes have taken place in a positive way and are reliable from the statistics point of view, which indicates the expediency of applying the developed content of environmental and economic competencies and its introduction into the structure of professional competency forming in the field of environmental and economic safety as the main component.

DISCUSSIONS

To create professional competence in the field of environmental and economic safety, which is necessary for a modern and competitive specialist in professional activities, it is necessary that the content of education contribute to the knowledge fundamentality, the integrative-holistic thinking forming, an eco-centric worldview formation, professional competence and readiness formation for forthcoming activities.

The professional competence formation problem among future techno-sphere safety engineers in the field of environmental and economic safety is topical, which is conditioned by the society and the state need for training specialists ready for work in conditions of unstable social, ecological and economic relations.

Based on the scientific, psychological, pedagogical, special and methodical literature system analysis of E.V. Murav'eva, A.D. Murzin, E.N. Prokofieva, E.N. Sedova, G.V. Surovitskaya, A.V. Verethekhin, E.F. Zeer, A.R. Shaidullina et al., L.R. Kayumova & V.G. Zakirova, T.B. Lisitzina et al., R.A. Kurbanov et al. [2, 3, 4, 5, 6, 7, 8, 37, 38, 39, 40], the state of the research problem was studied and specific characteristics of engineering and technical specialists' training were determined, and also the nature, structure and content of professional competence was revealed in the field of environmental and economic safety. The didactic basis was identified, the conditions and principles for selecting content integration were determined, the model of the techno-sphere safety specialist and the structural and functional model of the process for integrating the training content in the field of environmental and economic safety, as well as the methodology for implementing it, taking into account existing state educational standards were developed by the authors. The effectiveness of professional competence's formation in the field of environmental and economic safety by the example of an integrated special course's implementation using training integrative-modular technology was checked.

CONCLUSIONS

The study on professional competence formation in the field of safety on the developed special course basis and integrative-modular training technology application allowed us to draw a number of the following conclusions:

- the special psychological, pedagogical and methodological literature and normative documents analysis allowed to develop and define a combined notion "ecological and economic safety" and the notion "professional competence of the engineer in techno-sphere safety in the field of environmental and economic safety";
- the developed model's approbation for the specialist and the structural and functional model for integration of the training content confirmed the correctness of the selected approaches and the possibility for their use in other related educational institutions;
- the pilot work results testify to the students' training effectiveness in the field of environmental and economic safety to develop professional competence in the field of safety based on the application of integrative-modular training technology.

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