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Informative characteristics and methods of the formation mathematical competence of future engineer in the oil and gas business

Características y métodos para la formación de competencias matemáticas del futuro ingeniero en negocios de petróleo y gas

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Contents

ABSTRACT:
One of the main directions of modernization of vocational education is the formation of professional competence of the individual as a complex multifunctional structure. The article discusses the current state of problems of development of mathematical competence of future engineer in the oil and gas business. The definition of "mathematical competence", its structure, including the unity of the three components is given.
Keywords: mathematical competence, pedagogical conditions, engineer in the oil and gas business, componentry, rating, modular training

RESUMEN:
Una de las principales direcciones de la modernización de la educación vocacional es la formación de la competencia profesional del individuo como una estructura multifuncional compleja. El artículo discute el estado actual de los problemas de desarrollo de la competencia matemática del futuro ingeniero en el negocio del petróleo y el gas. Se da la definición de "competencia matemática", su estructura, incluida la unidad de los tres componentes.
Palabras clave: competencia matemática, pedagógico condiciones, ingeniero en negocios de petróleo y gas, componentes, clasificación, formación modular.

1. Introduction

In terms of updating technologies and engineering, new demands on graduates are being put, which entail changes in the education system: new state educational standards are being created, the curriculum are being changed, the concept of competence of a specialist is being introduced. It should be noted, that the basic element of the system of professional training of future engineers in the oil and gas industry in university is math education. Therefore, in the process of professional training in technical university an important role belongs to the formation of mathematical competence of the future engineer, which is a component of his professional competence.

Analysis of a number of psycho-pedagogical studies of such scientists as Gnedenko B. V., Kudryavtsev L. D., Palferova S. Sh. and others in the field of teaching mathematics to engineering students, as well as current position of practice of university shows that, despite a certain degree of theoretical elaboration of the identified issues, graduates of technical universities often face with difficulties associated with the inability to use mathematical apparatus for solving the engineering problems, i.e. they are not intended to use it in professional engineering activities (Gnedenko, 1981; Kudryavtsev, 1977; Palferova, 2003).

Thus, the analysis of psychological, pedagogical and methodical literature, studying of experience of teaching mathematics at University confirms the existence of a contradiction between the objective need of the society in the expansion of professional, including the mathematical, competence of specialists of the oil and gas industry and the lack of scientific validity of its formation among students of technical specialties at all stages of learning.

The necessity of solution of the specified contradictions defines the relevance of the study and determines its problem of defining scientific grounds for the creation and implementation of the model and pedagogical conditions of effective formation of mathematical competence of future engineers in the oil and gas business.

The aim of our study was theoretical basis and the working up structurally-substantial model of formation of mathematical competence of future engineers in the oil and gas business, as well as eduction and experimental verification of pedagogical conditions of its effective implementation.

The object of this study was the process of formation of mathematical competence of future engineers in the oil and gas business. As the subject of the study was structural and substantial model of formation of mathematical competence of future engineers in the oil and gas business and pedagogical conditions of its effective implementation.

In accordance with the theme, the aim of the study the following goals were set:

1) Determine the extent of working up of the problem of formation of mathematical competence in pedagogical theory and practice.

2) Clarify the essence, structure and content of definition “mathematical competence of future engineers in the oil and gas business”.

3) Develop, approve and implement in practice the structurally-substantial model of formation of mathematical competence of future engineers in the oil and gas business and to reveal pedagogical conditions of its effective functioning.

4) Test experimentally the set of pedagogical conditions conducive to the formation of mathematical competence of future engineers in the oil and gas business.

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2. Methodology

During solving the first task, we found that, despite the fact that in the theory and practice of pedagogy of higher education some experience of formation of mathematical competence of students was accumulated, the issue of formation of this competence of future engineers in the oil and gas business in vocational training remains insufficiently investigated.

On the basis of the analysis of psychological and pedagogical and methodological studies on identified problem in the course of solving the second task, we came to the conclusion that the mathematical competence of the future engineer in the oil and gas business, is a unity of gnoseological, praxeological, axiological components, which provide it with the ability to solve theoretical and engineering practical problems that are important in professional activity of modern specialist of engineering specialty.

Concurring with Vardanyan Y. V., Isaev I. F., Nasyrova E. F., Slastenin V. A., in the structure of mathematical competence of future engineers in the oil and gas business the following interrelated components were identified: gnoseological, praxeological, axiological (Vardanyan, 1998; Isaev, 1997; Nasyrova, 2006; Slastenin, 2001).

Identified structural components are in a symbiotic relationship and allow us to represent mathematical competence as a holistic phenomenon. Gnoseological component defines knowledge system as multitude of interconnected elements, representing a definite integral formation. Praxeological component combines totality of skills, training and life experience, allowing operating with mathematical knowledge in the process of solving theoretical and engineering and practical tasks. The axiological component is a motive and interest in educational and future professional activity, as well as professionally important qualities.

The third task was to develop and implement of structurally-substantial model of formation of mathematical competence of future engineers in the oil and gas business. As the model of formation of mathematical competence of future engineers in the oil and gas business we understand the description and theoretical substantiation of such structural components as purposeful, substantial, action-procedural, and effective-evaluative of such process. Effective functioning of the structurally-substantial model suggested the necessity to allocate the totality of pedagogical conditions.

In solving the fourth task totality of pedagogical conditions, conducive to the formation of mathematical competence of future engineers in the oil and gas business has been identified and experimentally verified in the course of experimental work, which consisted of three stages.

At ascertaining stage of the experiment we have performed diagnostics of level of formation of the components of investigated mathematical competence on the basis of the developed criteria and indicators, we studied the condition of each component, presence of significant difference was revealed. (Table 1. The results of a test for ascertaining stage of experimental work).

Table 1.

The results of a test for ascertaining stage of experimental work

Group	Levels						χ^2_{emp}	χ^2_{crit}
	Low		Medium		High			
	the number of students	%	the number of students	%	the number of students	%		
CG	21	61,8	8	23,5	5	14,7	-	-
EG1	24	70,6	5	14,7	5	14,7	0,892	6,0
EG2	23	67,6	5	14,7	6	17,7	0,872	6,0
EG3	19	55,9	10	29,4	5	14,7	0,322	6,0

Note: CG – the control group, EG – the experimental group.

To solve these tasks, following methods were applied: document analysis, testing, questionnaires, interviews with students and teachers, observation, studying the results of students` activity, the test diagnostics of knowledge and skills.

The results of the ascertaining phase of the experiment indicate that most of the students have low and medium levels of formation of mathematical competence. The presence of high level of formation of mathematical competence of future engineers in the oil and gas business is random. This fact confirmed the flaws in the system of mathematical education of students of technical specialties and led to the necessity for targeted work in order to improve the efficiency of the process under examination.

It should be noted that experimental work was carried out in natural conditions of educational process, groups were selected on the principle of equal a source of data, but in different groups individual pedagogical conditions varied, which were the subject to verification.

In the control group (CG) training was carried out during the implementation of the model without the allocated pedagogical conditions. In experimental groups the study was carried out with the use of the model and pedagogical conditions: in the first experimental group (EG1) a combination of the 1st and the 2nd pedagogical terms was implemented (the organization of training through the introduction of modular educational technologies; strengthening the practical orientation of the process under examination through the application of professionally oriented mathematical tasks); in the second experimental group (EG2) there is a combination of 2nd and 3rd pedagogical conditions (strengthening the practical orientation of the process under examination through the application of professionally oriented mathematical problems; application of pedagogical monitoring and self-monitoring to obtain objective information on the impact of the ongoing process and its immediate correction); in the third experimental group (EG3) totality of all pedagogical conditions was tested.

On the formative stage of the experiment the organization of educational process on the basis of the developed model and testing the pedagogical conditions promoting increase of efficiency of the process were carried out:

1. The implementation of the first pedagogical condition for the organization of training was carried out in experimental groups through the introduction of modular educational technologies. The application of this training technology provided targeted orientation of the educational process on the professionalism and competence. Feature of modular technology was the application of modular programs of cognitive and operational types. Implementation of cognitive objectives was provided by the theoretical content of the training material. Information content of modules was formed on gnoseological grounds, that is, around the basic concepts and methods of mathematics course. We applied modular programs of cognitive type in order to form the system of fundamental knowledge of students. Modular programs of operational type, reflecting the context of future professional activities, provided the practical part of educational content (Choshanov, 1996). Modular training gave the opportunity to distinguish groups of fundamental concepts, to group material compactly, to avoid repetition within the course and related disciplines.

Such arrangement of training helped to get an objective activity`s assessment of not only students but also teachers; to increase the level of professional training of students; systematize the training process; enabled the students to self-assess their learning activities.

2. The second pedagogical condition for strengthening the practical orientation of the studied process was implemented through the application of professionally oriented mathematical problems. The classification of professionally oriented mathematical problems was proposed in the framework of the basic mathematical sections that contribute to the formation of: skills to build mathematical models; communication skills; algorithmic skills; functional skills; geometric skills; scholastic abilities (Lazarev, 2006). At the same time the practical activities on the formation of mathematical competence included the providing of a future engineer by all the highlighted skills in the complex.

Such condition would reflect the interrelation between the content of mathematics education with the content of special disciplines and show the vocational and practical relevance of the mathematical knowledge of each section, facilitating the formation and motivation towards studying and future professional activities.

3. The implementation of the third pedagogical condition gave the opportunity not only to obtain accurate and complete information about the level of mathematical competence of students, but also to identify ways to achieve more effective results ща work. Besides, monitoring ensured the implementation of a feedback between achieved result and purpose, as well as adjustment of process of formation of mathematical competence. But if in the control group only the pedagogical monitoring was used, that self-monitoring was carried out in experimental groups, which allowed the students to adjust their behavior, to set specific goals, to predict the results of further work.

System of control and evaluation of students` progress had a great importance in the formation of mathematical competence for our study. One of this system`s form was the rating. Such system of control has stimulated the attendance and organized regular independent work of students, greatly enhanced the competitiveness in the process of studying, has strengthened the motivation to accumulation of knowledge, has excluded the chance during examinations, has ensured the protection of students against stress, and has increased the level of planning and organization of the process under examination. The rating system gave more reliable information on the effectiveness of educational activity of students, stimulated their initiative in performing more complex tasks. The use of ratings implies a differentiated approach. High-achieving students had the opportunity to carry out additional tasks of increased difficulty. They received forward tasks, were as consultants and understood the studying content better by helping fellow students. Low-performing students received the opportunity of individual promoting on the studying program. It was possible to retake the test with the aim of improving the assessment. The student was aimed to receive the highest number of points during studying of module by such rating. With the breakdown of points, the student could decide himself or herself whether it is beneficial for him of her to skip class, not do homework etc. He became the master of his points and managed them by himself or herself. We convinced that it is better to use the rating of cumulative character.

When allocating requirements to the compilation of the rating control, we were guided by requirements allocated by Rusina A.V.:

1. It is necessary to develop a system of individual tasks, including assessment for their execution in the total rating of the student.

2. The technology of getting rating points in each discipline must be accurate and definite.

3. In a mandatory manner each student must be notified with the method of calculation of the rating in each discipline.

4. Terms of getting points must be equal for all students, at all stages of studying.

5. Methodical documentation of rating assessment should be available for all students (Rusina, 1997).

However, the rating system of control has not exhausted all the forms of control used by us. For increasing the level of motivational component of mathematical competence, following Bekirova R.S, Verbitskiy A. A., Denisenko, S. I., we applied the game forms of control (Table 2. Game forms of control) (Bekirova, 1998; Verbitskiy, 2000; Denisenko, 2002).

Table 2.
Game forms of control

Game title	Short description
Blitz-game	It is expedient to apply not only at the beginning and ending of the module, but in the process of formation of mathematical competence.

	The aim of the game is to test skills, identify ignorance and inability of students, create the atmosphere of competition and stimulate the axiological component of mathematical competence. Game duration is 40 minutes. The game involves the whole group, which is divided into teams of 3 people. The teacher gives the forms with the tasks one for a mini group. Tasks with increasing ordinal number are getting more complicated, and the more complex the task is, the more points it is evaluated. During summarizing, students receive reward points and the results are logged. This game is usually applies in practical classes.
Press-conference	It is advisable to use not only in practical sessions, but also lectures. The duration of the game is determined by the teacher. The teacher names the topic of the lecture and says to ask him the interested question on the topic in 3-4 minutes. Then he systematizes questions on the content and starts to lecture. Structure of the lecture should be as unified whole. In practical classes the essence and methodology remain the same, but all the main roles are performed by students. It is recommended to change students, answering the questions with the goal of increasing outreach to all students with a survey.
"Journey to the Queen of Sciences" **(suggested by** **R. S. Bekirova)**	We propose the following game situation: the fantastic time machine is being crashed into the mythical realm of Mathematics, the key to start it belongs only to "the Queen of the Sciences" (named "Mathematics"). Duration of this game is 50-60 minutes. The players are divided into groups (teams) for 6-7 persons, they solve tasks individually during 35-40 minutes, and then for determining a unified decision to this group 5-10 minutes is given. Then the correct solution is reported and the participants appreciate every correctly done task by one point, and incorrectly done task earns 0 points. Then there is a calculation of individual and collective points. The master and members of a group have instructions. Manual to the master: the master distinguishes the participants of the game into groups, explains the conditions and rules of the game, gives tasks, checks evaluation of players, generalizes the results and sums up the game. Also he announces the correct answers. Instruction to the team members: every member makes an individual work, filling in the test in the column of "individual answer". Then, a collective decision is produced by filling in the column of "group answer". Then, having listened to the correct answers, each member counts the amount of achieved points. The master of the team additionally counts the amount of points of the group answer. The game is designed for applying in one of the first practical training.

3. Results and Discussions

Analysis of the results of observations, questionnaires, Internet test allowed us to conclude that the use of such educational technologies, the complex of professionally oriented mathematical tasks, pedagogical monitoring and self-monitoring helped to increase the effectiveness of the process of formation of mathematical competence of future engineers in the oil and gas business. Data obtained in control and experimental groups, indicate that the interrelation of selected components of the process of formation of examined competence, realization of their substantive content as well as the implementation of structurally-substantial model and the implementation of totality of pedagogical conditions contribute to the formation in the unity of gnoseological, axiological, and praxeological components of mathematical competence, and therefore increase the effectiveness of the process under examination (Table 3. Comparative results of changing of levels of formation of students` mathematical competence in the process of studying course "Mathematics" at the initial and final stages of experimental work).

Table 3.
Comparative results of changing of levels of formation of students` mathematical competence in the process of studying course "Mathematics" at the initial and final stages of experimental work

Group	Level						Value of χ^2_{emp}	
	Low		Medium		High			
	Beginning of EW	Ending of EW	Beginning of EW	Ending of EW	Beginning of EW	Ending of EW	At the beginning of EW	At the ending of EW
CG	61,8	35,3	23,5	44,1	14,7	20,6	-	-
EG1	70,6	8,8	14,7	61,8	14,7	29,4	0,892	6,93
EG2	67,6	11,8	14,7	47,1	17,7	41,1	0,872	6,366
EG3	55,9	8,8	29,4	47,1	14,7	44,1	0,322	8,342

Note: EW – experimental work, CG – the control group, EG – the experimental group.

Based on the data processing methods of mathematical statistics, there is a visible difference in the results of control and experimental groups, which tastifies that effectiveness of the pedagogical process under examination increases with the implementation of the marked by us pedagogical conditions, and in group EG3 the value of χ^2 - pearson criterion ($\chi^2_{emp} = 8{,}342$, $p = 0{,}05$) is higher than in other groups and exceed χ^2_{crit} which value is 6,0 (and $p = 0{,}05$), so that means that the distribution is very significantly different and these differences are significant and not casual. We have the right to consider, that this increase occurred under the influence of totality of marked pedagogical conditions, which means that only their comprehensive implementation contributes to solving the main task, namely formation of mathematical competence of future engineers in the oil and gas business.

It should be noted that the number of students with a low level of mathematical competence significantly decreased in group EG3, from 55,9% to 8,8%, in which the complex of pedagogical conditions was used, meanwhile in group CG – decreased only from 61.8% to 35.3%.

Increased number of students with a high level of mathematical competence in group EG3 – from 14,7% to 44,1% and in control group CG – from 14,7% to 20,6%.

There is a positive trend of formation of mathematical competence of students while studying course "Mathematics", namely, at the end of the experiment, the number of students with high level of formation of mathematical competence has increased significantly, and the number of students who were at low and medium levels, has decreased. It is worth noting that during the experimental work changes were monitored by us, according to the criteria of the level of mathematical competence`s formation, namely, according to cognitive, activity and motivation criteria. The students of the experimental groups during performing tasks of professional orientation showed a higher level of mathematical knowledge but faced with difficulties in the ability to apply this information. By the final stage of experimental work, they have gradually developed the necessity for participation in scientific-practical conferences, there has been a tendency to a more positive attitude towards studying and future professional activity, motivation to master mathematical competence has increased.

4. Conclusions

In conclusion, on the basis of carried out generalization of theoretical positions, results of experimental work we have formulated the main conclusions, identified opportunities for future research:

1. Despite the fact that in the theory and practice of pedagogy of higher education there is some experience of formation of mathematical competence of students, the issue of formation of this competence of future engineers in the oil and gas business in professional training remains unexplored.
2. In the course of realized theoretical studies the concept "mathematical competence of future engineers in the oil and gas business" has been made more exact, which we consider as the unity of the gnoseological, praxeological, axiological component, providing it with the ability to solve theoretical and engineering practical problems that are important in professional activity of modern specialists of engineering specialty.
3. In terms of competency-based approach, the structurally-substantial model of formation of mathematical competence of the future engineer has been developed, which is an integral complex of interrelated elements that form a unity, and which includes target, content, activity procedural, and result-evaluative components.
4. Totality of pedagogical conditions for the successful implementation of the structural model has been defined, substantiated and experimentally tested, and which includes: a) the organization of training through the introduction of modular educational studying technologies; b) strengthening the practical orientation of the process under examination through the application of professionally oriented mathematical problems; c) application of the pedagogical monitoring and self-monitoring to obtain objective information on the impact of the ongoing process and its immediate correction.

The study does not purport to completeness consider all aspects of the process under examination. In the course of work new tasks has been identified, which are needed to be solved. Further study can be continued in the following directions: development of alternative methods of diagnostics of level of formation of the components of mathematical competence and of training course of "Mathematics" through the introduction of new educational technologies.

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