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Professionally oriented mathematical tasks as a means of developing skills, which are necessary for a future engineer in the technical sphere

Orientación hacia tareas matemáticas para desarrollar competencias técnicas necesarias de un futuro ingeniero

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ABSTRACT:
The article discusses the possibility of implementing the principle of professional orientation in the teaching of mathematics, the purpose of which is formation of the mathematical aspects of readiness of future engineers to the professional occupation. As the requirements of professional orientation must be implemented both at the level of the selection and organization of course content, and at selection of methodological approaches to organization of educational activities, the author has attempted to show a complex of necessary skills and substantial aspect of course "Mathematics" in technical university on the basis of the proposed mathematical tasks.
Keywords: professionally-oriented tasks, students, skills, practical orientation

RESUMEN:
El artículo discute la posibilidad de implementar el principio de la orientación profesional en la enseñanza de las matemáticas, cuyo propósito es la formación de los aspectos matemáticos de la preparación de los futuros ingenieros para la ocupación profesional. Como los requisitos de la orientación profesional deben implementarse tanto a nivel de la selección y organización del contenido del curso como a la selección de enfoques metodológicos para la organización de actividades educativas, el autor ha intentado mostrar un complejo de habilidades necesarias y un aspecto sustancial del curso. "Matemáticas" en la universidad técnica sobre la base de las tareas matemáticas propuestas.
Palabras clave profesional orientado a las tareas, los estudiantes, las habilidades, la práctica de la orientación

1. Introduction

Modernization of education, the necessity for technological changes and transformation in technical sphere directs engineers to find ways of improving the quality of education. Among the possible directions of implementation of abovementioned points we consider the increasing in the applied orientation of educational process through the changing of the content of education, the target purposes, applied educational technology.

The applied direction of teaching involves the systematic revelation of the close relationship of applied and theoretical content of corresponding subject. In the process of implementation of applied orientation the role of the subject is revealed, as well as its methods in the discovering of the phenomena of the objective world. A striking example is "Mathematics".

A future engineer in a technical field must be prepared to solve professional tasks in the sphere of industrial-technological, organizational-administrative, scientific-research, project, and operation activities. We agree with point of view of Yu.M. Kolyagin, L. M. Fridman and mean by a task a certain situation, which must be solved taking into account the conditions, mentioned in it.

As the professionally oriented mathematical task we understand a task, a condition and demand of which determine a model of some situation, arising in the professional activities of the engineer, and the research of this situation is carried out by means of mathematics and contributes to the professional development of expert personality (Ilyashenko, 2015).

V. S. Lazarev suggests reformulating the professional tasks as competencies that need content (Lazarev, 2006). Each of them by us was concretized in detail in the context of several components, namely, a system of knowledge necessary to implement of this competence; general skills; professionally important qualities. Highlighted tasks must define the content of the mathematics course.

2. Methodology

During the application of professionally oriented tasks, future engineers can master the complex of skills and apply them practically in their professional activity, namely, to build mathematical models, communication, algorithmic, functional, geometric.

L. D. Kudryavtsev in his works repeatedly expressed the idea that the content of mathematical education should not be limited to the totality of mathematical knowledge and skills. As the result of study at University, according to L. D. Kudryavtsev, must become formation of the ability to be an expert in the mathematical methods, which are needed for working in the specialization, but which were not studied at University, the ability to read the scientific books, the ability to continue one`s math education independently (Kudryavtsev, 1977).

Such approach is particularly relevant at present when the development of science, technology, engineering is going on so fast that often the materials being studied by the student during training in University is already outdated and not applicable in practice by the end of University.

Before talking about the professionally oriented mathematical tasks, let us consider the essence of the concept of "task".

A. N. Leontiev defines task as an object where the condition and requirement is recorded, and which must be accomplished (Leontiev, 1981).

So, Yu. M. Kolyagin suggests to mean by task the system "man – task situation", where the second component of the system is a totality of interconnected elements via some properties and relations. If for the subject that came into contact with a situation at least one item, property, or attitude is unknown and the subject has the necessity to establish elements, properties and relationships of this situation, that are unknown to it, the situation becomes a task for this subject.

Turning to the concept of professionally oriented tasks, let`s note that as a given situation in it there is a model of professional situation in which according to the known parameters of the professional object or phenomenon it is necessary to find other its characteristics or properties.

Permit or research of presented, simulated situation contributes to the formation and development of skills that allows us to formulate the requirements for professionally-oriented tasks, used in the process of formation of mathematical competence of the future engineer:

- the task must describe the situation arising in the professional activities of the engineer in a technical field;
- characteristics of some professional object or phenomenon must be unknown in the task, which must be investigated by the subject according to the available characteristics by means of mathematics;
- the solution of problems must lead to a lasting digestion of mathematical knowledge, techniques and methods that are the basis of the professional activities of the engineer;
- tasks must provide the digestion of the relationship of course “Mathematics” with general technical and special disciplines;
- the content of the task and its solution require a knowledge of special subjects;
- solving of tasks must provide mathematical and professional development of the personality of the future engineer.

Analysis of psychological-pedagogical books has shown that there are different classifications of professionally oriented mathematical problems. S, V.V.Karpov, proposes to classify tasks according to the types of mathematical models and distinguishes four main types:

- mathematical models in the form of systems of linear equations;
- mathematical models in the form of differential equations and their systems;
- mathematical models of linear programming tasks;
- mathematical models of experimental processes (Karpov, 1992).

Other researchers classify professionally oriented mathematical tasks on the mathematical sections. The application of functions and the theory of surface areas and volumes of geometric solids to the solution of engineering tasks is being examined, the possibility of application of harmonic analysis to the calculation of various steel structures during action of variable loads on them is being described (Gnedenko, 1981).

Based on this analysis and other manuals, we have attempted to create a classification of tasks in terms of basic mathematical topics. In the proposed classification to each ability relates professionally oriented mathematical problems, contributing to the formation of:

- skills to build mathematical models (incomplete math tasks with missing data; tasks with dynamic forecasting; tasks involving data retrieval using simple experiment);
- communicative skills (tasks related to the fact-based and the theoretical levels of specialization);
- algorithmic skills (tasks with predictable results; and the tasks with the analysis of the obtained response);
- functional skills (construction tasks and reading graphs of functions; tasks of the transition to the analytical form of defining the function of tasks on the functional dependence);
- geometric skills (tasks in the construction of figures in flatness and space; tasks in finding the numerical characteristics of geometrical figures);
- stochastic abilities (tasks in the situation analysis; tasks in the analysis of the received response; tasks of assessment of reliability of the obtained answer; tasks related to the General theory of the experiment).

Solving such tasks, student will have to think about their specific condition, and the mathematical methods for their solution, i.e. there is a process of translating task`s statement into mathematical language. Introduction of tasks of professional type into educational process teaches students to see the universality of mathematical formulas, leads to the elements of mathematical modeling of professional tasks in various fields of science and technology.

For professional oriented mathematical tasks in order to be as a means of formation of selected skills, it is necessary to organize their systematic and purposeful application. For that reason the teacher must: analyze the basic didactic units of a part; display totality of didactic units in the aggregate of professionally oriented mathematical tasks; develop tasks that allow to check the level of the skills formation.

Thus, to our mind, application of professionally oriented mathematical tasks strengthens the practical orientation of the pedagogical process and determines for the synthesis of cognitive and practical activities of students.

3. Results and Discussions

The first the ability to build mathematical models contributes to the formation of skills to competently formulate and solve research and practical tasks. When constructing mathematical models the students are supposed to impose restrictions on numeric characteristics. Therefore, we asked students to solve tasks where the restrictions on numeric features were imposed for practical reasons. Such tasks are tasks of research type, as after reading the conditions the student is in a situation of uncertainty – there is lack of data that would allow us to formalize the task, namely, to build a mathematical model of the process under examination, to explore the interpretation of achieved results.

There is an important quality for an engineer to have the ability to get the source information for solving the task, because usually at first in real life there is a problem situation, and then the specialist collects the necessary data to resolve it. We have formed this ability during the solution of applied and incomplete application tasks with missing data. Students pointed out how they received the missing data. We give some examples.

Task № 1. It is known that the temperature of the salt solution to kill a borehole and its salinity is associated with a linear dependence. How to find this dependence using the least squares method?

Task № 2. Find the law of temperature change of the frozen or permafrost soils.

When solving such problems, self-dependent getting of data was meant; thereby was the prerequisite for the formation of skills to carry out tests, surveys, work with reference books, take various measurements etc.

We have also offered students the tasks associated with dynamic forecasting, as future engineers must be able to predict the development of phenomena in time. The students took the published data on the development of a certain phenomenon (oil production per year; the number of oil crews in Drilling Department, etc.), on their basis they have built a mathematical model of the development of this phenomenon over time; have predicted the level of development for the current period and compared with the real value.

We defined communication skills as the ability to work with information given in different mathematical forms, to read information written in mathematical language, to write information in mathematical language and to choose the best form of its presentation. For achieving this goal, we were offering students training and application tasks in which the recording of information in mathematical language or reading of information in mathematical language was one of the main goals. For example, they were the tasks in which it was demanded to use the matrix form of recording information.

Task № 3. There are (conditional) data on output per shift of oil production for one brigade *Y*, bed thickness *X1* and the level of mechanization operations *X2* (%), which characterize the process of oil production for 10 drilling rigs.

Presuming that between the variables *Y, X1, X2* there is a linear correlation, to find its analytical expression (equation of regression *Y* по *X1* и *X2*).

Also students were asked to imagine the practical meaning of such fundamental concepts of mathematical analysis as the limit of the function at the point and at infinity, continuity of a function at a point, the first and the second derivative of function, definite integral.

Task № 4. To determine the speed of movement of the liquid in pumping and compression pipe and in hole clearance of the borehole when washing downhole sand plug, if the performance of the pumping module is 13 liters per second. The info on the borehole: the diameter of the production casing is equal to 146 mm, pipe wall thickness equal to 10 mm, diameter is 73 mm, the wall thickness of pumping and compression pipe is equal to 5mm.

We should not forget that the students must be able to compare geometrical shapes to the real objects, so we tried to show the practical meaning of coordinate systems and proposed tasks, in which it was necessary to pass on geographical coordinates to mathematical ones and vice versa, to build a line (surface) according to their equations, or to write down conditions that set lines (surface) depicted in the figure.

Task № 5. There is a drill plan with a predetermined trajectory. Knowing the coordinates of the start and end points of the rectilinear borehole AB, find its length and azimuth that defines the direction of the borehole.

For the implementation of mathematical models, it is necessary to have determined algorithmic (in particular, computational) skills. The set of these skills was entirely determined by the contents of the Mathematics course. We have focused on developing skills to predict, test and analyze the answer. We have made sure that few of the students make "estimation", i.e., try to predict approximately what result should be obtained. Before solving we offered to the students to predict the result and to justify personal point of view, and after receiving a response to find out whether forecast justified or not.

If students were offered incomplete tasks with ready data and question formulated in mathematical language, in which it was required to find some value, then we usually pursued the goal of developing of algorithmic (computational) skills. But if the answer in such tasks was given in ordinary language (not "what is", but "does it make sense", etc.), then at the stage of interpreting the achieved response the ability to analyze the response has developed.

Task № 6. The dependence of the company`s profit on oil production from the borehole is governed by the law (law is being written). Does it make sense for the company to exploit this borehole, if its power is limited to 12 thousand tons per day?

Also computational tasks or associated with the solution of standard equations, inequalities, etc., in which the received answer contained settings contributed to development of ability to analyze the received response. Exploring the received answer under the possible values of the included parameters, the students considered special cases and compared them with the real situation.

Every specialist is needed functional skills, namely: be able to describe the dependencies between the variables; to predict what will happen to the dependent variable if the independent variable will continue to grow, aspire to a certain value, etc. We focused on the functional skills associated with the study of real dependences, which can be formed in the process of solving the professionally oriented problems.

Ability to build and read graphs of functions is inextricably interconnected. For the formation of the ability to read real graphics of real dependencies students have been proposed tasks-tests which offered to choose from several schedules the one that described the dependence between the real values. Then students were asked to predict which type will have a specific, actual dependence, for example, to sketch the graph of the dependence of oil viscosity on temperature of oil reservoir, the dependence of the fluid velocity in the pumping and compression pipe on capacity of pump rate, etc.

Also we offered tasks in which it was necessary to simulate functional dependence on the description of some its properties, for example, using the formulation and solution of the differential equation.

Task № 7. In cementing unit   TSA-320 there is *A* kg of cement, dissolved in *B* liters of water for insulation the aquifers from the petroliferous in the borehole. Then every minute the unit receives *M* litres of water and flows *N* liters of solution ($M > N$), and the concentration is maintained uniform by stirring. Find the amount of substance in the unit after *T* minutes after the process` starting.

Geometric skills are professionally important for engineers, who subsequently will have to work with real objects that can be mapped to geometric shapes. We offered to the students the tasks on determining the distance between the points specified in different coordinate systems, and then the tasks on determining the distance from a point to a certain line or the shortest distance between the lines. The tasks that require writing down the conditions that have been satisfied by the coordinates of sets of points shown in the figure contributed to the formation of the ability to specify geometric shapes in an analytical form.

We divided stochastic skills into probabilistic and statistical. Ability to build and implement probabilistic models is important for future engineers. The ability to analyze a situation and make the optimal solution is very important, especially if in the future professional activities future specialists are intended to engage in research work. The ability to describe and analyze the empirical results with the mathematical methods is professionally relevant (Ilyashenko, 2017). We offered tasks that required to determine the necessary number of experiments or estimate the accuracy of the received result depending on the number of held experiments, to describe how the experiments should be held – dependently or independently – and to assess how it will affect the result.

Besides the statistical and probabilistic skills, students should possess the ability to explain how the results of research can be used to practice, which usually are not entirely credible, and describe how it is possible with the use of practical experiment to prove or reject the hypothesis. Therefore, for solving, we proposed the tasks associated with the testing of statistical hypotheses, as they imitated the process of research work. In selecting these tasks, we payed attention for the hypothesis to be formulated in ordinary language, but in solving the task we emphasized the stage of interpretation of the obtained response.

Task № 8. For testing the effectiveness of new technologies two drilling crews were selected: in the first group the number is $n1 = 50$ people, where new technology was applied, a selective average output amounted to $x = 85$ (meters of drill cuttings), in the second group the number is $n2 = 70$ people, a selective average output amounted to $y = 78$ (meters of drill cuttings). Previously it is established that dispersion of output in the groups are respectively 100 and 74. Significance level is $\alpha = 0{,}05$, figure out the impact of new technology on the average performance.

The selected types of task were applied in all the main mathematical topics that allowed reflecting the interrelation between the content of mathematics education and the content of special disciplines and showing the vocational and practical relevance of the mathematical knowledge of each section, thus facilitating the formation and motivation for learning and future professional activities.

On the main branches of mathematics we have developed a complex of professionally-oriented tasks. Selection and preparation of the task was determined by the objectives of learning. Solving the given tasks of different difficulty levels, students used the mathematical knowledge and skills, acquired the ability to analyze a situation.

4. Conclusions

In the course of studying of mathematics, we have developed methods of teaching to solving of such tasks. Process of academic and scientific knowledge has happened stage-by-stage: the perception of the object; comprehension; formation of knowledge; acquisition of knowledge; transformation of knowledge.

The first step is logical-systematic. The purpose of this stage is to under-standing and perception of the educational information in the form of a system, a imprinting of a system of mathematical knowledge. At this stage, students were asked to get acquainted with symbolic and logic schemes, that reflect the structure of concepts (name, definition, designation, calculation formula, destination) that are necessary for solving tasks of a particular topic. The most important principle of building the system was structural properties – mapping elements, as well as the making communications and relationships between elements of the system.

The second stage is actualized, the goal of which is actualization of the theoretical knowledge for solving engineering and practical tasks. At this stage, we were offering to the students the system of typical tasks on the topic under examination. The students registered the results in the shape of a table (Table 1. Actualization of theoretical knowledge).

Table 1.
Actualization of theoretical knowledge

Statement of a task	**Calculation formula**	**Solution**	**Interpretation of the results**

For checking of results of work the students were offered a filled out the above table and in the graph "Solution" either the key moments of solution, or the most difficult moments of solution were reflected. The students checked their results on their own, understanding their mistakes.

The last stage is the searching, on which there was the transfer of knowledge into new conditions. For this purpose, students were offered the tasks for the finding of typical errors in the solution; tasks that have not only one method of solution; the tasks on the reversal train of thought: subsequent to the results to formulate the task statement.

So, strengthening the practical orientation of the pedagogical process through the application of professionally oriented mathematical tasks contributed to the formation of mathematical competence of the future engineer. At the same time, the practical activities included the providing of a future engineer with all the skills, dedicated in complex.

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