Mathematical Modeling in the Training of Future Mining Engineers

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Abstract. In the modern world, the introduction of mathematical methods in various subject areas. Today, many disciplines use methods of mathematical statistics, modeling, forecasting, and optimal planning. A student of a technical University majoring in «Mining», as a future engineer, often has to take into account many factors and rely on complex criteria for the effectiveness of ways to achieve final goals. Various modeling methods help you quickly find solutions to various problems. We offer students at the technical University to teach not only the fundamentals of higher mathematics, but also to teach them to build mathematical models and solve applied problems. Mathematical modeling helps students to see mathematics in life and future profession. It contributes to the development of mathematical competence of students, which is one of the components of their professional competence.

1. Introduction

One of the directions of development of modern higher education is the introduction of mathematical methods in various subject areas. Today, many disciplines use methods of mathematical statistics, modeling, forecasting, and optimal planning. This changes the requirements for mathematical training of future specialists and bachelors of technical specialties. The goal of mathematical training of University students today is the high development of their mathematical competence. The requirements to the applied orientation of mathematical training of specialists are increasing. The use of modern PCs in the implementation of the capabilities of the apparatus of mathematics allows you to automate the processes of information processing. This significantly increases the volume of information and the speed of its processing. One of the main areas of application of the PC is mathematical and technical calculations. The following software tools can be used for this purpose: 1) virtual mathematical laboratories; 2) table processors (QuattroPro, MSExl, etc.); 3) programming languages (Basic, Pascal, etc.); 4) packages of symbolic mathematics (Maple, MatLAB, Derive, Mathcad, etc.); 5) packages of statistical data processing (Statistica, etc.) [1].

A student of a technical University, as a future engineer, often has to take into account many factors and rely on complex criteria for the effectiveness of ways to achieve final goals. Various modeling methods help you quickly find solutions to various problems. The modeling methods that we consider in one way or another with students of various specialties are presented in table 1.

The most relevant and popular among specialists of technical specialties is the method of simulation.
| Modeling method | Description | Application | Advantages of the method | Disadvantages of the method |
|-----------------|-------------|-------------|--------------------------|-----------------------------|
| Mathematical    | It is the mathematical equivalent of a process or object that reflects its basic properties | Any processes that can be mathematically described | Wide application area | It is often quite difficult to build a model that adequately takes into account all the factors |
| Economics and mathematics | This section includes methods for solving economic problems | Economic process | The method is able to model economic processes | |
| Statistical | The model is based on the revealed statistical regularities | Processes for which an array of statistics can be collected | If you have high-quality data, the method is accurate, and if you have specialized equipment, it is easy to use | Large requirements for statistical data |
| Simulation | The system being studied is replaced by a model that describes the real system with sufficient accuracy, and experiments are conducted with it in order to obtain information | This method is used when it is expensive or impossible to use a real model | You create a model that is as close as possible to the real model, and you can manage the system's characteristics | Complexity of describing all conditions and requirements of computing power |

Simulation is a special case of mathematical modeling. There is a class of objects for which, for various reasons, analytical models have not been developed, or a method for solving the resulting model has not been developed. In this case, the mathematical model is replaced by a simulator or simulation model. Simulation allows you to test hypotheses, to study the influence of various factors and parameters.

Simulation modeling is widely used in teaching special technical disciplines in higher education. Using simulation methods, a number of optimization problems are solved, both at the development stage of the enterprise and for various stages of its operation.

The calculations in the mining industry often contain formulas with deterministic parameters. At the same time, many of the characteristics of the Deposit, the properties of the mineral, the external conditions of development and processing of raw materials are random. For example, a feature of gravel and sand deposits is the presence of boulders from 0.2 to 4 %. The average square deviation of the content of gravel and boulders for different blocks is 5-15 %, and the coefficient of variation is 12-32 %. As a result of the heterogeneity of the quality characteristics of the useful thickness of the
Deposit, the crushing and sorting plant receives raw materials with fluctuations in the content of gravel and boulders from 15 to 75%. This causes erratic operation, loss of productivity, and increased power consumption of the equipment. We can conclude that it is necessary to improve the methods of calculating mining machines and equipment, taking into account the random nature of the quantities that affect the final result. This task is successfully solved by using simulation modeling.

In order to better master this method, you need mathematical modeling skills. In order to better master it, you need mathematical modeling skills. Mathematics is studied by students majoring in «Mining» in our technical University in the first and second year, when they are not yet studying their special disciplines. As a result of mathematical training, students should get not only basic knowledge of mathematics, but also learn to solve applied mathematical problems. Of all the considered types of mathematical modeling, we focus on mathematical modeling in mathematics classes. Let's look at mathematical modeling in teaching mathematics in more detail.

2. Urgency
To develop the mathematical competence of technical University students, it is necessary to focus on the applied, professional orientation of mathematical training, to teach students majoring in «Mining» mathematical modeling. In this direction we studied the works of V. P. Boltyansky and L. M. Pashkov [2], B. V. Gnedenko [3], O. V. Petunin and L. I. Mamonova [4], M. V. Noskov and V. A. Shershneva [5], S. V. Plotnikova [6]. All of them are aimed at solving applied problems, studying mathematical modeling in the process of mathematical training of students. However, the application of applied problems and mathematical modeling for the development of mathematical competence of students of technical specialties of the University, as an integral part of their professional competence, has not been studied enough and is still quite a new educational technology.

The purpose of our research is to develop, implement into practice the teaching of each section of mathematics for students majoring in «Mining» practically and professionally oriented tasks as well as experimental verification of changes in the level of development of mathematical competence of students.

3. Theoretical part
A Mathematics for a student should be connected with his daily life, with his future professional activity. Any person enthusiastically studies a subject, if they are interested in it, and if this subject is important to them. Therefore, when studying each topic in mathematics, we try to focus on solving applied problems. In the classroom, we teach students to translate any technical problem into a mathematical language.

One of the mandatory aspects of mathematical training of students is teaching them mathematical modeling.

Every student, as a future mining specialist, should be able to build a mathematical model based on the available initial data. In his future professional career, he will have to solve the problems of organizing, planning and managing activities, with many possible solutions. The processes considered in the tasks can have a lot of uncertainty and dynamism. When working on an object, you need to compare different options and choose the most appropriate one. To solve all these problems, the student must learn modeling [7].

Examples of tasks.
1) Mining enterprise for further development put in the bank 100 thousand rubles, at 7% monthly. The Deposit amount is calculated using the simple interest formula. You need to find the dependence of the Deposit amount on the number of months that this Deposit will lie in the Bank, and answer the questions:
   a) what amount will be on the account in 4 years?
   b) how long will the Deposit amount increase by 1.5 times?
According to the task data, students compose a function and answer questions.
2) Mines A and B are located at a distance of 300 km between them. Mine A produces 250 tons of ore per day, and mine B produces 150 tons of ore per day. How to build a plant for processing ore, so that the cost of transportation was the least?

We make up a function and examine it: \( y = 250x + 150(300-x) \)

Students get home work, give examples of a linear function that describes real processes related to their future profession or life.

In practical math classes, we try to translate plot problems into mathematical language.

Studying the topic "Rows", students analyze a problem about two circus performers throwing knives at a target during a rehearsal. The rehearsal continues indefinitely. The sequence of hits for each artist can be represented as a series of numbers. In a more experienced artist, you can see that no matter how small a circle we take, starting with a certain hit, all subsequent hits will be inside this circle. This means that the sequence of hits converges to the center of the target, so the center of the target is the limit of the sequence of hits. Watching a less experienced artist, you can take a circle of some radius, such that no matter what number we do not think of, there will be a hit with a large number that falls outside of this circle. This means that the sequence of hits does not converge to the center of the circle. Then, in this example, we consider the criterion for convergence of the Cauchy sequence. Take any distance. Then we find a number such that the distance between any two hits with large numbers would be less than the intended distance. If, no matter how small a distance we have planned, it always turns out, then the sequence satisfies the Cauchy criterion. From this it follows that it converges.

An example of the theorem that every monotonically increasing and top-bounded numerical sequence has a limit is the example with entries for ultra-deep drilling. In 1984, a world record was set at the Kola well. The drilling depth there reached 12,066 m. The previous record well was developed in 1974 in the United States and had a depth of 95.83 m. Every year, several dozen ultra-deep wells are drilled in the world, reaching 6000 m or more, for the search and exploration of oil and gas fields.

A large number of mathematical models are built by students when solving problems on the topic "probability Theory, mathematical statistics and random processes". Let's look at one of these problems.

The car repair service for mining machines receives an average of 4 orders a week. The average time to repair one car is 5 days. 3 cars can be repaired at the same time. If the car service is already engaged in repair of three cars, new orders are not accepted. Find the probability of failure, limit state probabilities, and throughput (absolute and relative car service)."

For a unit of time we will choose one day (it was possible to choose one week). The number of channels \( n = 3 \). The intensity of the flow of applications \( \lambda = 4/7 \) (since one day is selected per unit of time).

\[
\bar{t}_{66} = \frac{1}{\mu} = 5, \text{ so } \mu = 5, \text{ a } \rho = \frac{\lambda}{\mu} = \frac{20}{7}.
\]

\[
p_0 = (1 + \rho + \frac{\rho^2}{2!} + \frac{\rho^3}{3!})^{-1} = \frac{1029}{12169} \approx 0,084;
\]

\[
p_1 = \rho \cdot p_0 \approx 0,242;
\]

\[
p_2 = \frac{\rho^2}{2} \cdot p_0 \approx 0,346;
\]

\[
p_3 = \frac{\rho^3}{6} \cdot p_0 \approx 0,328.
\]

Probability of system failure: \( P_{ot} = p_3 = \frac{\rho^3}{3!} \cdot p_0 \approx 0,328. \)

Relative throughput: \( Q = 1 - P_{ot} \approx 0,672. \)

Absolute throughput: \( A = Q \cdot \lambda \approx 0,384. \)

The average number of occupied channels: \( k = \frac{A}{\mu} \approx 1,92. \)

Similarly, you can study all the topics of the course of mathematics. Solving plot problems with students, teaching them mathematical modeling, we change the students ‘ idea of mathematics,
increase interest in its study, and increase the importance of new mathematical knowledge. This contributes to the development of mathematical competence of students, and hence the development of their professional competence.

4. Results of experimental work

As we said above, the goal of mathematical training in higher education is to develop the mathematical competence of students. An experimental work was carried out, in which 49 students majoring in «Mining» of the technical specialty took part in Nosov Magnitogorsk State Technical University. Two groups of students were selected for the experiment, one experimental, the other control. The control group of students studied the fundamental foundations of higher mathematics, classes in it were standard. In the experimental group, in addition to standard training, students solved applied problems and engaged in various types of modeling on each topic.

To prove the reliability of the obtained experimental results, two problems were solved. First, the methods of mathematical processing of the experiment results were selected, and second, the representativeness of the sample was proved.

To substantiate the reasons for changes in the results, the statistical criterion $\chi^2$ Pearson was used during the experiment [8].

Two problems were solved to prove the reliability of the results obtained as a result of the experiment. First, the methods of mathematical processing of the experiment results were selected, and secondly, the representativeness of the sample was proved.

To process the results of the experiment, the statistical criterion $\chi^2$ Pearson was used to justify the reasons for changing the results. The null statistical hypothesis reads as follows: "the levels of mathematical competence of students in the experimental and control groups will not differ as a result of the experiment."

Criteria and indicators of the level of development of mathematical competence of students were developed [9]. When processing experimental data, each indicator of the level of development of mathematical competence of students was evaluated on a three-point scale.

At the beginning of the first semester, primary data were determined, which showed a fairly low level of development of mathematical competence of students.

Selected criteria and indicators were tested for the level of development of mathematical competence in each of the groups at the beginning of the study of mathematics in high school (beginning first semester) and at the end of the discipline of mathematics in the University (end of third semester). The results are shown in table 2.

Table 2. Results of development of mathematical competence of students in the process OF experimental work.

| Group | Number of persons | Levels | low Quantity | medium Quantity | high Quantity | $\chi^2$ obs. |
|-------|-------------------|--------|--------------|----------------|--------------|--------------|
| EG    | 25                | start  | 12           | 48%            | 11           | 44%          | 2            | 8            | 0,2          |
|       |                   | finish | 2            | 8%             | 15           | 60%          | 8            | 32           | 6,0          |
| CG    | 24                | start  | 10           | 41,7%          | 12           | 50%          | 2            | 8,3          | -            |
|       |                   | finish | 8            | 33,3%          | 13           | 54,2%        | 3            | 12,5         | -            |

At the end of the course of mathematics at the University, repeated diagnostics were carried out. The experiment showed an increase in the number of students who are on the average and high level of development of mathematical competence.

According to the results of table 2, we see that at the level of significance $\alpha=0.05$ in the experimental group of $\chi^2$ obs. $> \chi^2$ critic. ($\chi^2$ crit. $= 3.84$), that is, the condition for the application of applied
problems and mathematical modeling in the mathematical training of students is statistically significant for the development of mathematical competence of students. According to the results of the work, we conclude that the successful development of mathematical competence of students of the technical University of the experimental group is not accidental, but is the result of the application of applied problems and mathematical modeling in mathematics classes.

5. Summary
All design solutions in the industry are mathematically justified, proven. Therefore, a student majoring in «Mining», studying in the technical direction of training at the University will not be held in the future as an engineer, if he does not know the theoretical foundations of mathematics, will not be able to build a mathematical model on the condition of a practical problem and solve it. Thus, a student should have a well-developed mathematical competence upon graduation.

The best results in the experimental group suggest that mathematical modeling in mathematics classes allows you to better develop the mathematical competence of technical University students majoring in «Mining».

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