FORMATION OF PROFESSIONAL COMPETENCE IN TECHNICAL UNIVERSITY STUDENTS DURING THEIR HIGHER MATHEMATICS STUDIES

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ABSTRACT. This paper is focused on the specific features that characterise mathematical studies of students enrolled in technical institutes of higher education. The four constituent components of academic preparation in mathematics – motivational, cognitive, activity-oriented and reflexive have been defined. Likewise, the basic mathematical competencies of every individual student who follow their degree courses in technical colleges or universities have been identified. Also, a point of special consideration has been the construction of a system of mathematical problems which aim at generating mathematical competencies during higher mathematics studies. A system of mathematical problems is proposed, that enhance the formation of basic mathematical competencies. Special emphasis is laid on the practical aspect of higher mathematics studies in technical universities as a basis for formation of professional competence in students; as well as on the role of mathematical modelling and the selection of contemporary interactive forms and methods of training, which involve application of ICT and suitable systems of computer mathematics.

Keywords: mathematical preparation, mathematical competencies, professional competence

ФОРМИРАНЕ НА ПРОФЕСИОНАЛНА КОМПЕТЕНТНОСТ В СТУДЕНТИТЕ ОТ ТЕХНИЧЕСКИ ВУЗ ПРИ ИЗУЧАВАНЕТО НА ВИСША МАТЕМАТИКА

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РЕЗЮМЕ. Предмет на настоящата работа са специфичните особености на математическата подготовка на студентите в технически ВУЗ. Дефинирани са нейните компоненти − мотивационен, когнитивен, дейностен и рефлексивен. Идентифицирани са основните математически компетенции на студента от технически ВУЗ. Разгледани са изискванията за конструиране на система от математически задачи, ориентирани към формирането на математически компетенции по време на обучението по висша математика. Предложена е система от математически задачи, формиращи основни математически компетенции. Специално място е отделено на практическата насоченост на обучението по висша математика в технически ВУЗ като база за формиране на професионална компетентност в студентите; ролята на математическото моделиране и избора на съвременни интерактивни форми и методи на обучение, включващи прилагането на ИКТ и подходящи системи на компютърна математика.

Ключови думи: математическа подготовка, математически компетенции, професионална компетентност

Introduction

A crucial determinant of innovative transformation of our education system at all levels is the application of competence approach. It is clear that the implementation of this approach means a significant reorientation of educational process. The main purpose of this reorientation is towards the personality of the trainee. This is undoubtedly related to new opportunities for professional training of future specialists, which will ensure their career development and success in the professional sphere.

Let us briefly consider the question of the necessity and effectiveness of the transition of Bulgarian education to the principles of the competence approach. We can distinguish between the following features of the competence approach: First of all, this approach takes into account the individual interests and abilities of the students. Secondly, orientation of the final result of education towards expansion of the educational space beyond the boundaries of formal education in the parallel structures of continuous education system. Thirdly, a process of informatisation of education implying use of information technology, methods and means of information science for implementing the ideas of development education. Fourth, intensifying the learning process at all levels and increasing its efficiency and quality.

Exposition

Undoubtedly, quality engineering education is based primarily on mathematics. The problems of mathematical education in pedagogical, classical and technical universities have been discussed in the works of renowned mathematicians, pedagogues, psychologists, philosophers and methodologists (M. Eraut, G. V. Dorofeev). There are many works of scientists and researchers devoted to the professional orientation of teaching mathematics in technical universities.

Within the competence approach, a technical university cannot provide its graduates with a corresponding level of competitiveness on the labour market, if it does not form the ability to adopt the achievements of fundamental sciences and their application in the corresponding engineering activity.

Therefore, it is essential to increase the students' desire to thoroughly master fundamental sciences, including mathematics, during their first year of study at a technical university.

The European Parliament and the European Council recommend a structure with 8 core competences:

1). Communicating in the native language;
2). Communicating in foreign languages;
3). Mathematical abilities and core competences in the field of science and technology;
4). Information competence;
5). Skills for learning;
6). Interpersonal, intercultural and social competences, civic competence;
7). Entrepreneurship;
8). Cultural self-expression.

Mathematical abilities and core competences in science and technology are listed under number three in the list of core competences. Mathematical abilities are related to availability of knowledge about basic mathematical concepts and categories, abilities to formulate mathematical statements, to understand mathematical proofs, to reason mathematically, to communicate in mathematical language, to use mathematical methods and ways for creating and solving mathematical models of real phenomena and processes.

Modern social development is characterised by global informatisation. The rapid improvements in ICT result in an increase in the information saturation of the public and professional activity of the individual. Skills to work with information, to create and study mathematical models, to perform mathematical calculations using mathematical packages and computer applications, as well as knowledge of ICT are core components in the structure of professional readiness and ability of the future specialists graduating from a technical university. This is a topical issue related to the formation of their professional-mathematical training. The development of systems of fundamental mathematical knowledge and skills, as well as the possibility of their application in the context of constantly developing information technologies, is one of the conditions for preparation of highly qualified specialists. The main idea of the competence approach in teaching is the coordination of the idea of *integration* of mathematics and informatics with professional-mathematical activity of students.

On account of the above analysis, it can be said that *mathematical preparation* of students from technical universities determines the ability and readiness of future engineers to solve problems arising in the sphere of engineering and technical activities. It is based on fundamental mathematical knowledge, practical skills and habits for mathematical modelling using mathematical packages and computer application software. It comprises the following components:

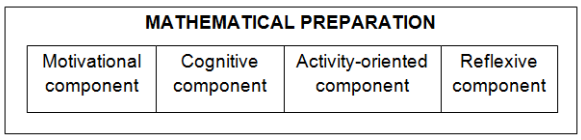

Fig. 1 Structure and content of mathematical preparation

The motivational component characterises the presence of value orientation, motives and interests aimed at professional-mathematical preparation and awareness of its importance for the future profession; interest on the part of the learners towards different activities in math classes.

The cognitive component of mathematical preparation determines the presence of theoretical and practical knowledge formed in the process of professional-mathematical training and self-training, facilitating the students to orient in the information space and to use mathematical packages for solving practical problems;

The activity-oriented component is a complex of activities aimed at self-regulation and skills to make decisions; elements of professional creativity, communicative competence and adequate self-assessment.

The reflexive component of mathematical preparation is aimed at reaching an informed solution to a given problem; to evaluate the process and outcome of self-acquired knowledge and to apply the experience gained from the training; to adequately evaluate their abilities; to form a sense of responsibility for their successes and failures in the learning process and professional activity, which is expressed in: self-assessment of the preparation for application of mathematical knowledge, skills, habits and competences in professional activity (Izvorska, 2017, 128-129).

As has already become clear, the competence approach does not deny the necessity to form a knowledge base and a set of skills and habits, but it is about achieving an integrated outcome – the formation of competence. So, let's take a brief look at the concepts "competency" and "competence".

The concept of "competency" is a successful combination and a set of skills, knowledge, attitudes and behaviour of employees to achieve results in a given professional sphere. Competencies in this meaning should be understood as *ability to self-organise*. By "*competencies*" we shall understand *a set of skills, knowledge, attitudes that are used to perform a successful, professional activity*.

The concept of "competence" is *a personal quality (a set of qualities) that is necessary to perform concrete activities in a particular subject area*. Competence is the ability of the person to perform a particular type of activity successfully, effectively and efficiently; to act skilfully in competitive situations; to make proper choices; to assess his abilities and resources adequately in order to make the right decisions. Competence includes all-round knowledge, skills, habits and behaviour in any field of activity that are necessary for obtaining quality and efficiency. It characterises the outcome, the quality of the professional training and includes both professional preparation (above all, information and technical preparation) and a system of nonprofessional knowledge that every specialist should possess.

In short, *Professional competence* of a specialist is a set of abilities and personal qualities, as well as knowledge and experience necessary for successful professional activity in one or another sphere. (Eraut, 1994).

Bearing in mind the objectives of education, the following mathematical competencies are identified that students enrolled in technical institutes of higher education should possess:

1) ability to use the analogy method;

2) ability to analyse – ability to see the new sides of a given mathematical object;

3) ability to synthesise – ability to find the common in different mathematical objects;

4) reversibility of the thinking process – ability to switch from direct to reverse thought; this ability is the link between ability to analyse and ability to synthesise;

5) generalisation – ability to summarise the mathematical material; to separate the important from the unimportant; to divert the attention from the insignificant; to see the common in the different and the different in the common;

6) systematisation skills – ability to translate a problem or a way to solve it into an algorithm for its further solution or analysis;

7) ability to translate the problem into the "language of mathematics" – ability to isolate the mathematical problem from the real problem and to rephrase it into a mathematical problem;

8) mathematical intuition – ability to quickly find the right solution and to orient in different situations in order to predict the course of events.

Since the mathematical problem is an essential tool for forming mathematical competencies in students, mainly during their practical math classes, the following *functions* can be defined:

- mathematical problems are an essential tool for developing students' reasoning in the process of math training;
- the problem is an essential means of achieving learning objectives; a means of activating, managing and individualising learning;
- the use of a system of problems designed in accordance with certain levels of knowledge acquisition (algorithmic, recognition, generalisation, creativity) allows the process of mathematical competency formation in students to be manageable;

The following *basic requirements* for construction of a system of mathematical problems oriented towards mathematical competency formation during mathematics studies are set:

- hierarchy (the levels of adoption of the basic components of mathematical knowledge: algorithm, recognition, synthesis, creativity should be the basis for constructing the system of problems);
- adequacy of activity management (the number of problems should be such that the students should move from more rigorous activity management to less severe, taking into account the difficulty limit);
- alternativeness of activity management (the system of problems should be such that the students can compare different approaches to solving mathematical problems in order to be able to assess their effectiveness and relevance);
- error provocation (the system of problems should contain problems developed on the basis of common misconceptions and common mistakes of students);
- procedural (the problem presented to the students should be defined so that they can control not only the outcome of their activity but their progress as well);

Formation of *mathematical competencies at algorithmic level* includes: mastering the algorithm which consists in developing the mathematical processes and their sequence; the application of the algorithm – its development in familiar and unfamiliar situations. As consecutive operations in the prescriptions of the algorithmic type of problems, such problems should be proposed, the solution of which requires the student to be able to overcome tolerable difficulties. For example elementary operations from algorithmic prescriptions can be proposed in higher mathematics studies along with problems requiring the use of definitions, theorems, formulae, as well as previously solved mathematical problems. Thus, the students receive a task with absolutely precise instructions for all steps that have to be accomplished in order to solve the problem. Such tasks can help to develop the ability for clear and consistent accomplishment of all stages of an activity and to facilitate the accomplishment of activities that prove to be difficult for the students.

Problem 1. Find the vertical asymptotes for the function graph

$$y = \frac{x^4}{(x+1)^3}$$

The sequence of operations is as follows:

1) Find the definition area (DA) of the function.

2) Find the limits of the function at the ends of DA.

3) Draw conclusions and write down the vertical asymptote equations.

Problems at *algorithmic level of training* may only contain a general notion of the method of action. Instructions for performing such tasks may be suggested in view of the difficulties likely to be faced by students when solving the respective problems. This type of activity determines a higher level of formation of mathematical competencies in students. Problems of this type may be the following: problems with indication of the theorem to be used for solving them; proof-oriented problems with use of well-known facts or requiring additional drawing tasks; problems with indication of method(s) of solution; problems for which an instruction is given to use the method of solution for an already solved problem (Yagova, Zubkov, 2013).

In mathematical training it is essential that students are able to recognise concepts, to apply theorems, to use different mathematical methods to solve problems in specific circumstances or contexts and to be able to explain their choices. The problems for forming mathematical competencies at a *recognition level* should be selected taking into account the basic concepts and theorems learned in mathematical classes, which the students have mastered and can distinguish (recognise) among others.

When most of the topic "Differential calculation of function of one variable" has already been studied, the students should be able to select from many examples those in which the application of logarithmic differentiation is first necessary, and secondly rational.

Problem 2. Choose from the following functions those for which the derivative can be found:

1) only by logarithmic differentiation;

2) logarithmic differentiation is the most rational way to find the derivative;

а) $y = \ln(x^2 + 2x) - 3$ б) $y = \frac{x^2.3^x}{\cos x.\ln x}$

b) $y = 3\arcsin(5 - 2x)$ г) $y = (\sin x)^{2x}$

c) $y = \frac{\lg(3x-2).arctgx}{\cos x}$ е) $y = (8x-3)^{13}(x+11)^{23}$

Find the derivatives of the selected functions applying logarithmic differentiation. Find derivatives of the same

functions without using logarithmic differentiation. Compare solutions and results.

The problems aimed at forming mathematical competencies at a *generalisation level* imply the need to emphasise the properties of the object, to analyse their relationship, to generalise typical examples, to reconstruct the mathematical learning material. Such tasks are as follows: to retrieve the condition of the problem through the result; to change the dependences in the result resulting from the change in the condition of the problem. On the basis of several typical examples, it is suggested to find the patterns of the solution and to obtain general formulae or rules for the solution.

For the problems requiring *retrieving the condition of the problem through the result*, the end result of the solution is given in the form of a mathematical expression. The students are supposed to retrieve the original expression and to describe the process of obtaining the result. These tasks are intended to enhance the students' ability to make transformations leading to the end result. As an example of a problem requiring retrieving the condition of the problem starting from the end result obtained, the following is suggested:

Problem 3. By calculating the limit of the function in ***a*** we have the following:

$\lim\limits_{x\to a}\dfrac{2x^3-2x^2}{5x^3-4x^2}=\dfrac{1}{2}$ Find ***a***.

Solution: $\lim\limits_{x\to a}\dfrac{2x^3-2x^2}{5x^3-4x^2}=\lim\limits_{x\to a}\dfrac{x^2(2x-2)}{x^2(5x-4)}=\dfrac{1}{2}$

$\dfrac{2x-2}{5x-4}\to\dfrac{1}{2}$ with $x\to 0\Rightarrow a=0$

Through problems requiring change of the dependences in the end result arising from changes in the condition of the problem students are supposed to learn to establish causative links. A specific change in the condition results in a corresponding change in the end result. Such tasks aim to enable students to master the ability to solve prognostic problems.

Problem 4. Solve the inequality $\int\limits_0^a(2-4x+3x^2)dx\le a$, $a>0$.

Despite the fact that this inequality seems to be unusual (contains an integral) and is perceived as an inequality with a given parameter, it is not difficult for first-year students to use the Newton-Leibnitz formula. The inequality is reduced to a simple algebraic inequality and the following result is obtained: $a=1$.

Students are then asked the following questions:

1. How does the function *f*(*x*) change, so that the solution of this inequality is the interval [5; $+\infty$)?
2. Suggest your own inequality, like the one you have, the solution of which is $a=3$
3. Suggest a solution to an inequality in general, if *f(x)* is a square function, by considering all parabola positions.

By answering the above questions the students learn to construct, to put hypotheses, to summarise the obtained results. All these actions are a step towards formation of mathematical competencies.

The choice of problems to form mathematical competencies, whose *solution requires a creative approach*, must be based on the possibility for students to develop such qualities of the mind as depth, flexibility, stability, awareness of their thinking process and autonomy in acquiring and using new knowledge.

Problem 5. Is the function $y=3^{-x^2}+x.\sin x$ even?

Those students who have not developed the ability to deviate from the stereotypes will check the equation $y(-x)=y(x)$. Those students who possess such qualities of the mind as intellectual agility and can rely on past experiences will consider the function as a sum of two functions: $y_1=3^{-x^2}$ and $y_2=x.\sin x$, and prove that these are even functions. Then according to the well-known theorem, it is concluded that the sum of two even functions is even.

In the process of performing such creative tasks students will discover other important aspects of the learning material. Opportunities are being created for the students to use effectively and efficiently their mathematical abilities to master the learning material and to apply it creatively in concrete situations.

We can state that students from technical universities should:

- be aware of the role of mathematics in both their professional activity and in mastering the basic professional knowledge and skills;
- be familiar with basic mathematical methods used to solve applied problems from their professional field;
- to be familiar with basic concepts and methods from branches of higher mathematics, such as mathematical analysis, discrete mathematics, linear algebra, analytical geometry, complex number theory, probability theory and mathematical statistics;
- to be familiar with theoretical basis of differential and integral calculus;
- to be able to solve standardised math problems and applied problems in the field of their professional activity;

The special characteristics of mathematical preparation of students following degree courses in technical colleges or universities set a number of requirements to the organisation of the training in mathematical subjects, content, means and methods of training.

Training in higher mathematics in technical universities has a practical focus which includes:

- revealing the significance and importance of mathematical knowledge as a prerequisite for formation of professionals with higher technical education who will be capable of working in contemporary market economy conditions;
- application of the principle of interdisciplinary integration. This is particularly important when developing curricula in the respective degree courses;
- use of basic mathematical methods that are applied in solving practical problems. This implies focusing the attention on the methods and ways of creating mathematical models that adequately meet the demands of modern manufacturing;
- use of modern interactive forms and methods (study groups and group discussions, interactive seminars, business and role games, etc.) to present the learning material, including an electronic version;

- choosing between several modern forms and methods used in mathematical training in the system of higher technical education;

- application of ICT (computer and software use, internet, multimedia) and appropriate computer mathematics systems, such as MathLab, MathCad, Maple, etc.

The effectiveness of mathematical preparation depends on the *pedagogical conditions*. We can determine the following pedagogical conditions: forming a sustainable motivation to study mathematics; application of personality development methods; designing the content of the discipline.

Conclusion

Summing it all up, the following *conclusions* with regard to the issues pointed out in the research paper can be made:

1. Professional competence (PC) of a specialist graduating from a technical university is multifaceted and integrated concept.

2. Mathematical preparation is an integral part of PC of students enrolled in technical institutes of higher learning.

3. The task of forming PC is closely related to the formation of common competencies that are responsible for the development of such important needs and abilities of future professionals as conscientious work, creativity, self-development - these are all qualities for which mathematical training plays an important role.

4. Training in mathematics in technical universities through creation and analysis of mathematical models of applied mathematical problems has a significant potential for formation of PC in future engineers.

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