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Original Article

Development of Mathematical Competences among Future Teachers as the Result of Computer Technology Application

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Abstract

The relevance of this article is conditioned by the fact that qualitative preparation in mathematical disciplines and the presence of mathematical competencies are necessary for a future teacher of the natural science cycle to perform his professional functions, for an adequate application of mathematics to solve the problems arising in everyday life. In this regard, there is the need to search for more effective technologies of higher mathematics teaching, which is the methodological basis of natural scientific knowledge. The authors single out the theoretical analysis of the pedagogical literature as one of the leading methods in the study of this problem, on the basis of which the definition of natural science teacher mathematical competences was formulated and the pedagogical experiment that substantiated the effectiveness of the Mathematica system in the study of mathematical subjects. The main results of the study include the allocation of four levels of mathematical competence (low, medium, high, very high) and the definition of core competence list that are developed during the classes in higher mathematics. The significance of the obtained results is in the solution of such a major scientific problem as the development of mathematical competencies among the future teachers of the natural-science cycle with the use of computer technologies in teaching. The results of the research fill the existing gaps in the theory of higher education, contribute to the solution of higher mathematics teaching motivation issues among the students of pedagogical departments at universities.

Key words: Mathematical preparation, Information technologies, Mathematical competences, A teacher of the natural-science cycle, Computer system Mathematica

INTRODUCTION

Nowadays, one can not help noticing the objective contradictions between the needs of modern society in competent teachers of the natural scientific cycle that apply adequately mathematical and computer methods and models in their professional activity and the real level of readiness to use information technologies; The availability of computer systems that allow to increase the level of professional training of future teachers, and the insufficient elaboration of the theoretical and practical bases for their use in the learning process. Regarding mathematical preparation, these contradictions are concretized in the contradiction between the need to develop the mathematical competences of future teachers of the natural scientific cycle and the traditional approaches to the organization of the learning process. Taking into account the mentioned above, the main problem of the research is formulated: how to develop the mathematical competencies of future teachers on the basis of information technology use. The purpose of the article is to substantiate theoretically and test experimentally the efficiency of computer technology use for the development of mathematical competencies among future teachers of the natural-scientific cycle.

Assessing the coverage of the topic, it is possible to single out the works on general pedagogical problems for education improvement [1], [2], [3], in particular, the improvement of mathematical education [4], [5], [6]. The choice of information technologies is conditioned

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by sufficient theoretical and practical development of education informatization problems, carried out from various positions. Recently, the methodical aspects of computer technology application in the teaching of higher mathematics were considered in [7], [8], [9], [10], [11], [12].

Under the mathematical competencies of natural science teachers, the authors understand the complex of characteristics (integral and personal-professional) of graduates from the pedagogical departments of universities of natural science professions, which manifest themselves in theoretical and practical readiness and the ability to use of acquired mathematical knowledge, skill system in the professional activity at a high pedagogical level due to the qualitative mastering of mathematical education content.

The development of a broad mathematical erudition among the students of natural sciences, based both on knowledge in various mathematical disciplines, and on the experience of their interdisciplinary use is ensured by using computer technologies at higher mathematics classes.

As the main factors that determine the pedagogical feasibility of information technology means implementation in the process of higher mathematics teaching, one can single out an immediate feedback between a user and the means of information technologies; The possibility to change and enrich the content of material; Computer visualization of educational information about objects or the patterns of processes and phenomena; Automation of computing processes, etc.

Among the main directions of computer technology use in education, one can attribute the use of applied software systems for the computerization of complex mathematical calculations, which makes it possible to learn the most difficult sections of a particular discipline better and more quickly to a certain extent.

The need for special mathematical systems at a university during the study of mathematical disciplines is conditioned by the fact that, first of all, a modern teacher should be oriented towards the use of modern software to carry out various mathematical calculations; secondly, the use of these systems will make the problems solved during a class more difficult. Thirdly, their use makes it possible to increase the share of independent work in the educational process, since they allow to solve research problems to a greater degree.

We believe that the use of Mathematica computer system during mathematics classes motivates students to study this discipline and ensures the effectiveness of the entire learning process.

METHODS

We propose to use the method of step-by-step of calculation verification using the Mathematica system. Here is an example of a problem with a solution.

The task. To compute an indefinite integral:

$$\int \frac{(x-1)}{x^2(x-2)(x+1)^2}dx \ .$$

Solution.
Let's put in the following notations:
A - calculation by the traditional way (manually);
B - the check of a performed action with the Mathematica package.

I. A) Let's record a given proper fraction

$$\frac{(x-1)}{x^2(x-2)(x+1)^2} \ .$$

We decompose the integrand into the following simple fractions:

$$\frac{(x-1)}{x^2(x-2)(x+1)^2} = \frac{A}{x^2} + \frac{B}{x} + \frac{C}{x-2} + \frac{D}{(x+1)^2} + \frac{F}{x+1}.$$

We reduce the last equality to the common denominator and discard it:

$$x-1 = A(x-2)(x+1)^2 + Bx(x-2)(x+1)^2 +$$
$$Cx^2(x+1)^2 + Dx^2(x-2) + +Fx^2(x+1)(x-2).$$

Hence, multiplying the brackets and giving such terms, we will have the following equation:

$$x-1 = (B+C+F)x^4 + (A+2C+D-F)x^3$$
$$+(-3B+C-2D-2F)x^2 = +(-3A-2B)x-2A.$$

B) In[1]:= Collect[A (x-2) ((x+1)^2)+B (x (x-2) ((x+1)^2))+C (x^2) ((x+1)^2)+D (x^2) (x-2)+F (x^2) (x+1) (x-2),x]

Out[1]=-2 A+(-3 A-2 B) x+(-3 B+C-2 D-2 F) x^2+(A+2 C+D-F) x^3+(B+C+F) x^4

II. A) Equating the coefficients at the same powers of x in both parts of the equation, we obtain the system of equations to determine the coefficients A, B, C, D. F:

$$\begin{cases} B + C + F = 0, \\ A + 2C + D - F = 0, \\ -3B + C - 2D - 2F = 0, \\ -3A - 2B = 1, \\ -2A = -1. \end{cases}$$

Having solved the system manually, by the expression of one variable of the equation through other variables of the same equation, and substituting it into the following equation, etc., we obtain the following

$$A = \frac{1}{2},\quad B = -\frac{5}{4},\quad C = \frac{1}{36},\quad D = \frac{2}{3},\quad F = \frac{11}{9}.$$

B) In[2]:= Solve[{B+C+F= =0,A+2 C+D-F= =0,-3 B+C-2 D-2 F= =-0,-3 A--2 B= =1,-2 A= =-1},{A,B,C,D,F}]

Out[2]={{A→ 1/2,B→ -5/4,C→ 1/36,D→ 2/3,F→ 11/9}}

III. A) Thus, we obtain the decomposition of a rational fraction into the simplest elements:

$$\frac{(x-1)}{x^2(x-2)(x+1)^2} = \frac{1}{2x^2} - \frac{5}{4x} + \frac{1}{36(x-2)} + \frac{2}{3(x+1)^2} + \frac{11}{9(x+1)}.$$

B) In[3]:= Apart[(x-1)/(x^2 (x-2) (x+1)^2)]

Out[3]=1/(36 (-2+x))+1/(2 x^2)-5/(4 x)+2/(3 (1+x)^2)+11/(9 (1+x))

IV. A) Integrating, we obtain the following:

$$\int \frac{(x-1)}{x^2(x-2)(x+1)^2}dx = \frac{1}{2}\int\frac{dx}{x^2} - \frac{5}{4}\int\frac{dx}{x} + \frac{1}{36}\int\frac{dx}{x-2} + \frac{2}{3}\int\frac{dx}{(x+1)^2} + \frac{11}{9}\int\frac{dx}{x+1} =$$

$$= \frac{1}{2}\int x^{-2}dx - \frac{5}{4}\int\frac{dx}{x} + \frac{1}{36}\int\frac{d(x-2)}{x-2} + \frac{2}{3}\int(x+1)^{-2}d(x+1) + \frac{11}{9}\int\frac{d(x+1)}{x+1} =$$

$$= -\frac{1}{2x} - \frac{5}{4}\ln|x| + \frac{1}{36}\ln|x-2| - \frac{2}{3(x+1)} + \frac{11}{9}\ln|x+1| + C.$$

An original integral was represented as a sum of five integrals, the first and the fourth of which represent the table integral $\int x^n dx = \frac{x^{n+1}}{n+1} + C$, and all the others represent $\int \frac{dx}{x} = \ln|x| + C$.

B) In[4]:= Integrate[1/x^2,x]
Out[4]=-1/x
In[5]:= Integrate[1/x,x]
Out[5]=Log[x]
In[6]:= Integrate[1/(x-2),x]
Out[6]=Log[-2+x]
In[7]:= Integrate[1/(x+1)^2,x]
Out[7]=-1/(1+x)
In[8]:= Integrate[1/(x+1),x]
Out[8]=Log[1+x]

V. B) In[7]:= Integrate[(x-1)/(x^2 (x-2) (x+1)^2),x]
Out[7]=1/36 (-18/x-24/(1+x)+Log[-2+x]-45 Log[x]+44 Log[1+x])

The wide use of the Mathematica system was the impetus to the fact that we applied it in the teaching of students to some of mathematical discipline topics for step-by-step verification of the performed mathematical operations. For three years we selected two groups of first and second year students as experimental ones. We developed a comprehensive methodology, which included a traditional study of the topic, i.e. the performance of tasks manually, and using the computer system Mathematica. Methodical recommendations were made for students on the study of certain topics (classroom and independent ones). Each topic was divided into two classes.

RESULTS

Classes had the following structure:

1) a brief introduction to the topic and the necessary functions of the Mathematica system;
2) students performed individual assignments in two ways: manually and step by step using the Mathematica system.

Based on the results of the tests, we obtained Table 1.

This allowed us to make the following conclusions:

1. The students of junior courses had difficulties in the typing of commands during first classes because of programming skill absence. Therefore, the quality indicators for manual task performance exceed the same parameters during the solution of problems in the Mathematica system. In the future, the same quality

Table 1: Results of tests at the I^st^ and the II^nd^ courses

	Manual solution of tasks				Решение задач в пакете Mathematica			
	Advancement		Quality		Advancement		Quality	
	I sem	II sem	I sem	II sem	I sem	II sem	I sem	II sem
I st course								
I year	83%	78%	56%	55%				
II year	83%	83%	67%	60%	83%	92%	58%	83%
III year	75%	85%	60%	60%	75%	90%	55%	70%
II nd course								
I year	88%	77%	62%	50%				
II year	93%	80%	71%	50%	71%	90%	57%	65%
III year	80%	80%	50%	50%	90%	100%	70%	70%

and performance indicators during the solution of problems in the Mathematica system for both courses already exceed the same indicators during the solution of problems manually.

2. However, freshmen are faster trained to the application Mathematica system for mathematical calculations than second-year students already accustomed to the traditional study of higher mathematics. Therefore, the quality and performance indicators for both methods of problem solution for first-year students are practically the same ones. Among the second year students, the indicators of quality and the solution of tasks manually already slightly exceed the same indicators during the solution of problems in the Mathematica system. In the future, during the first course, the indicators of quality and advancement in test solution by both methods already exceed the same indicators among the second-year students. Therefore, it is necessary to begin the teaching of higher mathematics with the verification of the performed actions using the Mathematica system starting from the first year.

Then, having combined the students who studied mathematical analysis in a traditional way in a control group, and the students who studied mathematical analysis using the Mathematica system and Internet technologies in an experimental group, we performed the comparative analysis of the examination session results on this subject in both groups (Table 2).

Table 2 shows that the achievements of the first semester among the students of the experimental group determine further successes. Students' residual knowledge is checked at the end of the next semester, during the practical lesson; or the examination tickets include the task on professionally important topics of the previous semester.

Four levels of mathematic competences are defined ($K_{cm} = \frac{P_{cm}}{100}$, where $P_{ст}$ – a student's rating per semester, $K_{ст}$ - the mathematical competence coefficient):

1) $0,5 \le K_{ст} < 0,7$ (low level), 2) $0,7 \ge K_{ст} < 0,8$ (average level), 3) $0,8 \le K_{ст} < 1$ (high level), 4) $K_{ст} = 1$ (very high level). All the obtained data indicate that the experimental group has reached a sufficient level of preparedness.

Table 2: Comparative analysis of examination session results on mathematical analysis for the control and experimental groups

Grades\amount	5, 4		3		2	
	I	II	I	II	I	II
Experimental group	69%	72%	25%	25%	6%	3%
Control group	52%	52%	39%	37%	9%	11%

DISCUSSION

The main drawbacks of step-by-step calculation verification method using the Mathematica system include:
1) Large costs of study time during the first classes;
2) The reduction of the total number of examples;
3) Often external mismatch of correct answers.

You can also highlight the main advantages of calculation step-by-step verification method in the Mathematica system:
1) The timely finding of errors in the calculations;
2) Students acquire practical skills for mathematical reasoning conduct and the analysis of the obtained results;
3) The development of thinking components such as flexibility, structure, etc. among students;
4) The possibility of in-depth analysis of the task variants in the process of classes, the informative value of practical class increase;
5) Rapid development of the computer skills, intensification of independent work.

The effectiveness of the Mathematica system application during the classes in higher mathematics is confirmed by the experiment, which makes it possible to use it at pedagogical departments of higher educational institutions.

The performed experiment also made it possible to distinguish the list of additional competencies that are developed among the students of junior courses during the study of higher mathematics with the use of special computer mathematical systems to solve a certain type of mathematical problems (for example, the Mathematica system for stepwise verification of the performed mathematical operations). They include:
- Elementary computer skills;
- The ability to acquire new knowledge (not only mathematical ones), using modern educational and information technologies;
- Research abilities, the abilities to learn;
- Know one of foreign languages (have the ability to translate mathematical terms and recommendations from English language);
- The ability to apply basic knowledge in the field of informatics and modern information technologies in practice;
- To have an idea of the latest achievements of science;
- The ability to work independently and in a team;
- To have the ability to apply analytical and numerical methods to solve the tasks with the use of ready-made software;
- To have perseverance and persistence in the achievement of goals;
- The ability to use specialized knowledge in the field of informatics for the mastery of core information disciplines;
- Be able to solve mathematical problems and the issues from various areas of mathematics, which require some originality of thinking, etc.

At the same time, it should be noted that during the classes this type of competences, which will be developed by students at senior courses, are developed from the first year of study at a university.

All this indicates that the application of the Mathematica system is appropriate when individual subjects of mathematical disciplines are studied by university students.

With all the diversity of teaching technologies, the implementation of the leading pedagogical functions remains with a teacher. When you choose a particular software for the use in his work, a teacher inevitably faces the need to prefer one or the other of them. He should not forget that a modern expert should be a creative person, be able to take correct, often non-standard decisions in complex situations, be ready for continuous self-education, have a system-oriented style of thinking. It is the professional competence of such an expert that is the ultimate goal of education and the main characteristic of its quality. The basis for these problems solution is the qualitative mathematical education of university graduates, achieved in the process of competently selected package of applied mathematical program use in the process of preparation for higher mathematics.

CONCLUSIONS

The authors of this article clarified the concept of mathematical competences for the future teachers of natural science disciplines. The following possibilities of computer technology application in teaching for the development of mathematical competencies among future teachers of the natural-scientific cycle are revealed and substantiated: depending on the level of mathematical competencies development among the future teachers of the natural-scientific cycle, special computer mathematical systems must be used to solve a certain type of mathematical problems.

SUMMARY

The conducted research showed that the application of the Mathematica system for step-by-step verification of the performed mathematical operations is an expedient one in the study of individual topics of higher mathematics by future teachers of natural science disciplines.

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