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Original Paper

Students' mathematical competences and exam results

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ABSTRACT

In the paper we focus on the most common logical errors in the mathematical thinking of students at the Slovak University of Agriculture in Nitra. Error analysis was based on student tests. The tasks in the tests were focused on the use of basic issues related to functions taught at the Faculty of Engineering, Slovak University of Agriculture in Nitra (SUA). The main hypothesis was that students´ results are better at final exams than at mid-term tests taken during the term. In formulating the main research hypothesis, we relied on the theoretical knowledge of the issue and the experience based on our own teaching. Pedagogical experiment was conducted in two groups. We compared the results of mid-term tests taken during the term with final exams in certain subjects to see whether the differences between study outcomes of students were significant.

KEYWORDS: function, teaching mathematics, mistakes of students, mathematical statistics

JEL CLASSIFICATION: C02, C11, I210

INTRODUCTION

Mathematics develops students' mathematical thinking that is necessary in solving a variety of problems in everyday situations, when mathematical models of thinking (logical and spatial thinking) and presentations (formulas, models, diagrams, graphs, tables) must be used. The aim of teaching mathematics at faculties of Economics is to teach students mathematical methods that will become a means of solving applied problems.

Teaching skills development must be based not only on efforts of teachers, but also on activities of students. We focus on teaching functions and their use in technical disciplines. Teaching mathematics, in general, contributes to the development of not only mathematical, but also functional thinking. Today, elementary mathematical knowledge and its insights into opportunities are considered to be at least as important as the knowledge of the national history or the laws of physics. Different ways of thinking have come along with the development of mathematics. Issues of math education are still a priority; we talk about an increasing competence of both, students and modern math teachers. Quality requirements of

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a mathematical education are still very topical. Mathematical knowledge affects the level of development of other disciplines: computer science, electronics, electrical engineering, medicine, economics, etc. Teaching mathematics conveys a specific curriculum on one hand, on the other hand it develops logical thinking. In teaching mathematics it is necessary to apply logical procedures, which can be used in solving mathematical problems as well as applying them in practice. In mathematics, the tasks are very often solved by using mathematical logic that supports the development of the logical thinking at the same time.

Pietrikova [4] verifies the validity of described hypotheses about the dependence of preferred educational styles with one of the respondents' group. The examination submitted the existence of statistically verifiable difference between preferred educational styles for all students in connection with the attended type of secondary school. As regards the students' group – boys the dominance of any educational style was not confirmed. Vice versa the statistically verifiable dependence between the age resp. the type of attended school and preferred educational style was determined for girls.

Hornyák Gregáňová [1] says that the education is basic tool for acquiring expert knowledge, which affects human capital of the labour market and professional mobility and adaptability of human resources at the labour market. It is important to educate university undergraduates for practice by using appropriate and suitable educational methods. Országhová [3] determines that some of the principal indicators can have an impact on these results. The compulsory subjects are taught in the first year of the study and this could be associated with the students' adaptation to the university system. Our students come from different types of secondary schools and they also have a different level of mathematical knowledge. Many of students assume wrongly that the university study will not contain the subject of Mathematics. Certain difficulties in the study of mathematics can be caused by the abstractness of the math language and the contents, as well. Moreover, requirements of the self-study are difficult for some students, and it is reflected in exams.

MATERIAL AND METHODS

Mathematical analysis is a part of the higher mathematics, which is taught at all faculties at the SAU in Nitra. The question remains what part of teaching mathematical analysis should be compared to other parts of mathematics. In teaching functions, there is a discussion on how to teach students to understand the terminology of functions correctly, because only in the context of the terms we can talk about mathematical sentences. The aim is to correctly understand definitions and sentences, be able to use them in further study or in solving mathematical or technical problems. The aim is to choose a teaching method that will clearly show students different concepts so that they can combine them into the right sentences. This method should contribute to a more efficient study of mathematical knowledge.

To determine the level of students' knowledge of mathematical analysis, we have decided to conduct a research involving students of the Faculty of Engineering (FE) at the Slovak Agricultural University in Nitra. To increase the mathematical competencies of students, we have set the following research objectives:

• to explore the level of students' knowledge in selected mathematical topics focused on functions,

• to compare the level of mathematical knowledge between two different groups of students of taking the course Mathematics for Technicians taught at the FE in Nitra – the mid-term test and the final exam,
• to analyse errors and procedural errors in solving individual test tasks.
In formulating the main hypothesis of the research we relied on both, the theoretical knowledge of the issue and the experience based on our own teaching practice.

Main hypothesis:
H: Involving mathematical functions into other parts of mathematics will improve a quality of students' knowledge.

The pedagogical experiment was carried out in two groups – the experimental and the control one. We were observing the changes that had occurred as a consequence of changed conditions in the experimental group (mid-term test evaluation) compared to the control group (the exam evaluation). The observation was used as an additional research method; its general objective was to identify some pedagogical phenomena and facts. When observing, we focused on a few selected activities: working alone and solving tasks in front of the class. The students themselves were the object of the observation. The goal was to find out the level of students' knowledge of mathematical logic and to determine their ability to use propositional logic in other fields of mathematics.
Location of the research: Nitra, SUA, Faculty of Engineering, 1st year students
Research time: winter term 2017/2018
Content targeting test: The test included four tasks. Every correct answer was worth six points or two points, an incorrect answer zero points.

Examples of the mid-term test:

Example 1. Determine the domain of each of the following functions $f:\quad y=\sqrt{\dfrac{4x-8}{-3x+9}}$.

Example 2. Find the interval of real numbers, where the function
$f:\ y=x^4-4x^3-48x^2+23x+8$ is concave.

Example 3. Finding the tangent line: Suppose you are asked to find the tangent line for a function $f:\ y=\dfrac{2x+3}{3x-2}$ at a given point $x = 1$.

Example 4. Write a necessary condition for extreme values.

Examples of the final exam test:

Example 1. Determine the domain of each of the following functions $f:\quad y=\sqrt{\dfrac{4x-8}{-3x+9}}$.

Example 2. Find the interval of real numbers where the function
$f:\ y=x^4-4x^3-48x^2+23x+8$ is concave.

Example 3. Finding the tangent line: Suppose you are asked to find the tangent line for a function $f:\ y=\dfrac{2x+3}{3x-2}$ at a given point $x = 1$.

Example 4. Write a necessary condition for extreme values.

RESULTS AND DISCUSSION

The results obtained in the research were processed by different statistical methods. The analysis of the results is presented in the form of texts, graphs and tables. 74 students participated in our research. The main task of the research was to compare two research samples in the control and experimental groups.

The control group

The control group consisted of 74 students. The number of gained points in individual tasks, their percentage and the total number of points in the control group for each task is given in the Table 1.

Table 1: Gained points in the test (control group)

Task No.	**1**	**2**	**3**	**4**	**Total**
100 % of points	444	444	444	148	1480
Gained points	235	237	261	79	812
Success rate in %	52.9	53.3	59	53.4	54.9

The above table shows that the lowest average success rate was achieved in the task No. 3 - Determine the domain of each of the following functions and No. 4 – find the interval of real numbers where the function is concave. The highest level of knowledge was found in the task No. 3 - find the tangent line.

The experimental group

There were 74 students in the experimental group. Students of this group were working on the tasks aimed at applying mathematical functions in solving problems.

The total number of points in the experimental group for each task is given in the Table 2. This table also shows a sum of points for each task, the percentage of gained points for each task as well as the overall evaluation of the test.

Table 2: Gained points in the test (experimental group)

Task No.	**1**	**2**	**3**	**4**	**Total**
100% of points	444	444	444	148	1480
Gained points	290	281	283	98	952
Success rate in %	65.3	63.2	63.7	66.2	64.3

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When we compare both groups, it is clear that in the experimental group the total success rate increased by 9.4 %. The Table 2 shows that the lowest average success rate was reached in the task 2 and task 3 considering the sets of numbers. The highest level of knowledge was recorded in the task number 1 and 4. Evaluation of success rate in individual tasks in both, the experimental and the control group is shown in the Figure 1.

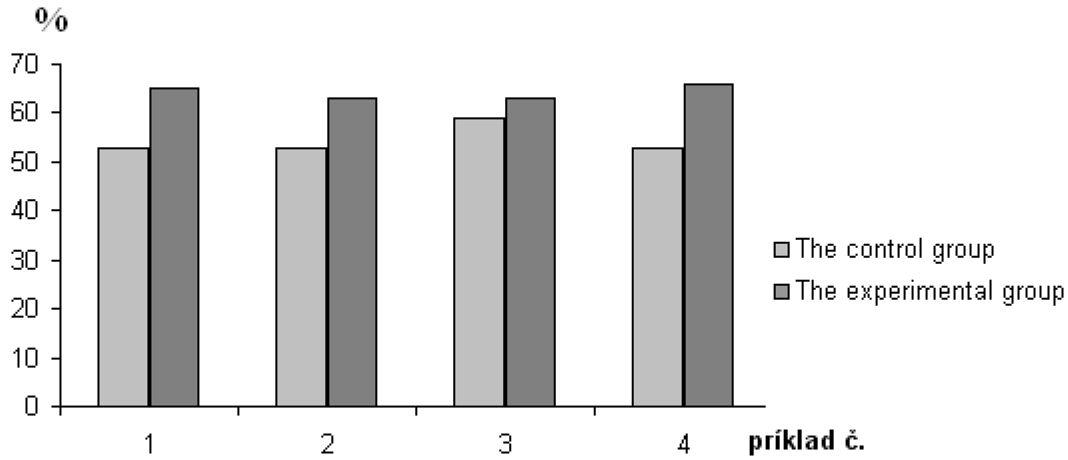

Figure 1: Evaluation of success rate in individual tasks

Testing equality of variances

In statistics, an F-test for the null hypothesis which says that the two normal populations have the same variance is sometimes used, although it needs to be used with caution as it can be sensitive to the assumption that the variables have this distribution [2]. Let's assume that samples are realizations of random selections from the normal distribution $N(\mu_1,\sigma_1^2)$ and $N(\mu_2,\sigma_2^2)$, and we will test the hypothesis, which says that variances in both groups are equal, versus the hypothesis that the variances are different (Tab. 3).

Test problem is: $H_0 : \sigma_1^2 = \sigma_2^2$ versus $H_0 : \sigma_1^2 \neq \sigma_2^2$

The F-test table brings $F = 1.574956$, the critical value where the level of significance is 0.025 and a test of significance is 1.473367, i.e., $F > Fkrit(1)$, and therefore the equality of variances is rejected.

Table 3: *F*-Test for Equality of Two Variances

	Control group	Experimental group
Mean	10.97297	12.86486
Variance	12.65679	8.036283
Observations	74	74
F	1.574956	
P(F<=f) one-tail	0.027075	
F Critical one-tail	1.473367	

Testing the level of students' knowledge in control and experimental groups

Because we have rejected the equality of variances, we are going to use the Two Sample Assuming Unequal Variances t-test in our testing. We will test the null hypothesis, which says that the level of students' knowledge is the same compared to the alternative hypothesis.

Our test problem: $H_0: \mu_1 = \mu_2$ versus $H_1: \mu_1 \neq \mu_2$

Table 4 shows that the statistical value of the t-test is - 3.57766. A critical value for statistical significance is 1.65589. Since the absolute value of the t-test is bigger than Critical Values, then the hypothesis H_0 is rejected. We accept the hypothesis and claim that the average level of knowledge in these groups was significantly different.

Table 4: t-Test: Two Sample Assuming Unequal Variances

	Control group	Experimental group
Mean	10.97297	12.86486
Variance	12.65679	8.036283
Observations	74	74
t Stat	-3.57766	
P(T<=t) one-tail	0.000239	
t Critical one-tail	1.65589	
P(T<=t) (2)	0.000478	
t krit (2)	1.977178	

By statistical evaluation we have found out that the involvement of mathematical function into individual parts of mathematics brings better results. Students could not find ways to recognize the elements of a certain group to differ it from the other groups; they generalized terms in tasks being solved on the basis of inadequate or secondary characters. This was evident in false arguments that students reported as reasons for incorrect solutions. Mentioned errors can be eliminated by mathematical functions in other areas of teaching mathematics (differential calculus, definite integral, indefinite integral, differential equation), not only in teaching mathematical functions. Figure 1 shows that students, who studied mathematical functions in other parts of mathematics during the term, achieved much better results in all exercises.

By statistical evaluation, we have found out that students achieved better results from individual parts of mathematics in the final exam compared to mid-term tests. The functions were also used by students in other parts of mathematics (differential calculus, integral calculus, differential equations), in which basic knowledge of functions had to be used. This is the reason why better results were seen at the final exam. The problems were that students could not find the right way to solve the tasks correctly; tasks were solved by the wrong methods. Mentioned errors can be eliminated by using definitions and theorems about functions in other areas of math's education.

CONCLUSIONS

Results of the research showed that the students achieved better results in the final exam. As a result, we can say that during lectures and seminars, there was no time to show students how to use theoretical maths in practice. In our opinion, teaching functions does not necessarily mean a waste of time, because mathematical concepts are linked together and functions are used in other parts of mathematics, too. These deficiencies caused that students did not understand the terms and principles of mathematical logic. Teachers work hard to change students' attitude to mathematics by introducing new methods. These are:

- explaining new terms by way of illustrative examples,
- specifying new terms in detail,
- determining the relationship between the terms by solving theoretical and practical tasks,
- drawing attention to the wrong ways,
- using the knowledge of mathematical logic in working with terms, definitions and theorems.

By using appropriate teaching methods, the learning process as well as students' knowledge can be improved. One way to eliminate these shortcomings is to track the right and wrong ways of thinking of students and to include functionalities into selected areas of mathematics.

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