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Original Paper

Mathematical and statistical methods in the analysis of study results of economy and management students

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ABSTRACT

The paper presents a comparison of exam results in mathematics and statistics at the Faculty of Economics and Management of the Slovak University of Agriculture in Nitra. Feedback is an important part of the educational process, and its quality can be assessed through the analysis of exam results. The main goal of this paper is to compare the exam pass rates of FEM students studying in all study programs at the bachelor's degree in the subjects of Mathematics IA, Mathematics IB, Statistics IA and Statistics IB in the academic years 2017/18 to 2020/21. We used ANOVA to verify the existence of differences in students' final evaluations. In those cases where we identified a difference in evaluations of subjects in the compared periods, we carried out an analysis by means of the Scheffé's test for Multiple Comparisons. In the monitored years 2017-2021 we confirmed only minimal differences in the grades awarded to students in the subjects Mathematics IA, IB and Statistics IA, IB.

KEYWORDS: Mathematics, Statistics, exams outcomes, average grade, post hoc comparisons

JEL CLASSIFICATION: I21, C12

INTRODUCTION

According to [8], investments in human capital, including education, skills upgrading, the development of education and science, are nowadays a significant prerequisite for the further development of society and its economic growth.

Society development can only be achieved if there is a sufficiently skilled and educated workforce that stimulates the national economy [9].

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According to [5], universities search for possibilities to attract students, to offer them an education of a high quality and to bring value added and differentiation to the university education.

Mathematical methods and procedures in applied forms constitute a base for interconnection and development of professional knowledge in the areas of economic policy, state economics, business management, accounting, regional development etc. [1], [2], [11].

The main aim of mathematics teaching at SUA in Nitra is to provide students with mathematical methods and their application in solving practical problems [7].

Teaching of mathematics and statistics has had a long tradition at the Faculty of Economics and Management of the Slovak Agricultural University (FEM SUA) in Nitra. The subjects Mathematics and Statistics provide apparatus and methods that have applications in scientific and professional activities in various fields. The content, methods and forms used in mathematics education at universities change according to the current requirements of professional departments, new educational trends, and practice [4].

According to [6], the aim of teaching mathematics at faculties of Economics is to teach students mathematical methods that will become a means of solving applied problems. The bachelor's degree study programs at FEM SUA in Nitra include Mathematics IA in the winter semester of the 1st year of study, Mathematics IB in the summer semester of the 1st year of study, Statistics IA in the winter semester of the 2nd year of study and Statistics IB in the summer semester of the 2nd year of study. These subjects are designed in a way that their successful completion is a basic prerequisite for the completion of professional subjects in the field of economics and management, where the acquired knowledge is applied primarily to solutions of case studies and work with real values, whether at the micro or macroeconomic level. All the above-mentioned subjects are provided by the teachers at the Institute of Statistics, Operational Research and Mathematics of FEM SAU in Nitra.

MATERIAL AND METHODS

The subjects Mathematics IA, Mathematics IB, Statistics IA and Statistics IB form the knowledge basis of the bachelor's study programs at FEM SAU in Nitra. These are the subjects whose knowledge is further required in professional subjects of bachelor's and engineering studies taught at FEM SAU in Nitra.

We investigated and compared the pass rate of FEM students studying in all study programs at the bachelor's study level in the subjects of Mathematics and Statistics in the academic years 2017/18 to 2020/21. In the first year of study each student completed the subjects Mathematics IA (Mat IA) and Mathematics IB (Mat IB) in consecutive semesters, and subsequently the subjects Statistics IA (Stat IA) and Statistics IB (Stat IB) in the second year of study. In all cases students' knowledge is evaluated, in order to minimize the influence of subjective evaluation, on the basis of preliminary written tests during the semester and the final examination test. The result is a final evaluation of the student's knowledge in accordance with the ECTS scale A(1), B(1.5), C(2), D(2.5), E(3), FX(4).

To assess the level of students' knowledge in individual subjects it was used basic descriptive statistics - arithmetic mean, which expresses the average grade of all students in the group, in our case for each subject in assessed time periods separately. The calculated average value

can be distorted by the existence of extreme values, and therefore it is appropriate in some cases to use the value of the mode which is defined as the most frequently occurring value of the investigated statistical characteristic. In addition to these two characteristics, it is also necessary to use the characteristic of variability to fully describe the investigated phenomenon [3].

The subject of the investigation is the final evaluation of students completing these subjects in three consecutive academic years. A generalized ANOVA t-test [10] is used to compare several means for independent sets. The basic hypothesis is formulated in a way that there is no difference in the average grade awarded to students in individual academic years. As an alternative hypothesis we used the claim that at least in one examined period the average grade was different than in other academic years. If the alternative hypothesis is not rejected, it is necessary to perform paired tests of agreement for all pairs of mean values, so-called contrast tests. For compared statistical sets with different ranges it is recommended to use the Scheffé's test for Multiple Comparisons [3]. The value of the test statistic is calculated as the absolute value of the difference of the compared mean values. The critical value for each pair of comparison is defined by the relation (1).

$$Critical\ value = \sqrt{\left(\frac{1}{n_i} + \frac{1}{n_j}\right)(m-1)s_r^2 F_{\alpha(m-1,n-m)}} \quad (1)$$

where:
n_i, n_j – frequency of the *i*-th or *j*-th set, students in *i*-th or *j*-th academic year,
m – number of compared levels, number of academic years,
s_r^2 – residual variance calculated for the compared subject,
$F_{\alpha(m-1,n-m)}$ – tabulated value of *F* distribution.

RESULTS AND DISCUSSION

In the paper we evaluate the exam results in subjects Mathematics IA, Mathematics IB, Statistics IA and Statistics IB with the aim to find out whether there are statistically significant differences between the exam results in these subjects. We used the exam results from the above-mentioned subjects in the academic years 2017/18 – 2020/21. Exam results from these subjects are evaluated in accordance with the standard ECTS scale A(1), B(1.5), C(2), D(2.5), E(3), FX(4).

The number of students at universities is determined by the demographic structure of the population, also manifested in the evaluated period, when the number of students enrolled in the first year copies the decline in birth rates in the years 1999-2003. Figure 1 shows the number of students who were obligated to complete the evaluated subjects in the given academic year. The number of students in individual semesters of the same academic year does not have to be the same since some students, due to the previous unsuccessful completion of the subject, were obligated to enroll in this subject repeatedly.

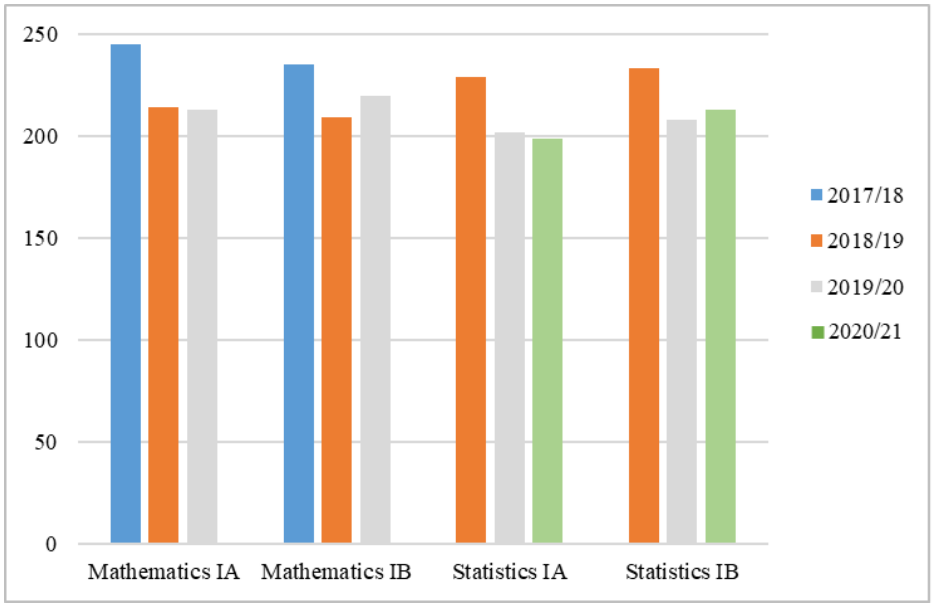

Figure 1 Number of students obligated to complete a compulsory subject

Table 1 Comparison of students' successfulness in subjects

Academic year *	Mathematics IA		Mathematics IB		Statistics IA		Statistics IB		Academic year *
	average	mode	average	mode	average	mode	average	mode	
17/18	2.24	3.00	2.37	3.00	2.43	2.50	2.22	2.50	18/19
18/19	2.35	3.00	2.35	3.00	2.32	2.50	2.25	2.50	19/20
19/20	2.30	3.00	1.82	1.00	2.26	2.00	2.24	2.50	20/21

* Students completed Mathematics IA, Mathematics IB in the academic year listed in the left column and Statistics IA, Statistics IB in the following academic year, which is listed in the right column.

It is clear from the graphic display that the number of students for the survey is sufficient. In the analyzed periods the grade E(3) was most frequent grade in the subjects Mathematics IA, IB. In the subjects Statistics IA, IB the students were most often evaluated with the grade D(2.5). These facts were reflected in the average grade value, which for both subjects ranged between 2.22-2.37, with the exception of the subject Mathematics IB in the academic year 2019/20, when students were most often awarded an A(1), and this made the average value of 1.82. The best evaluation in the group of statistics subjects was found in the winter semester of 2020/21, i.e. in the immediately following period, when students with the best results in the subject Mathematics IB completed the subject Statistics IA (Table 1).

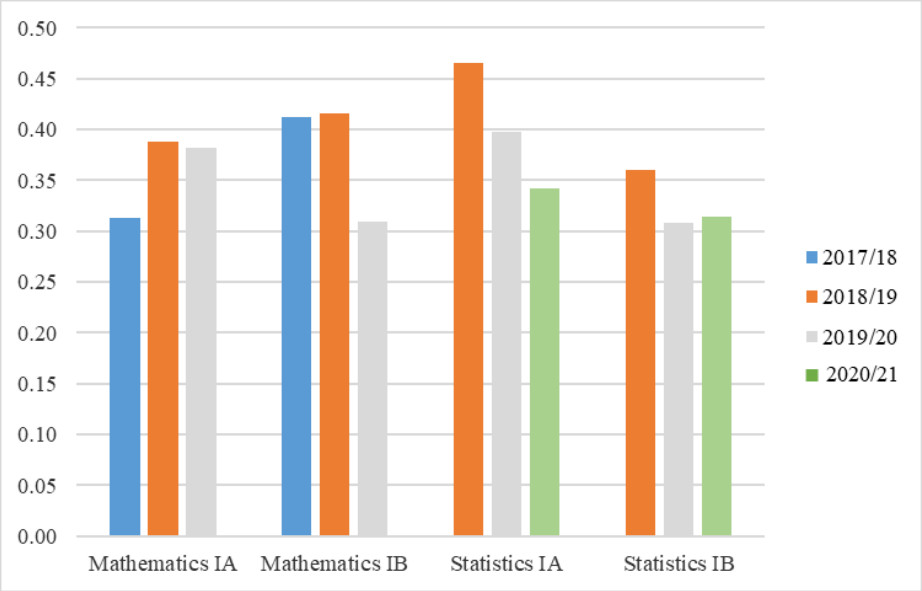

Figure 2 The share of the mode value in the overall rating

The evaluation of the pass rate of students as a whole in individual subjects or semesters appears to be good and balanced and can be considered as satisfactory in the context of the achieved results. In our opinion, however, it is necessary to take into account another way of assessing the pass rate, e.g. the share of the largest group of students, the so-called modal class, whose share varies from 30.91% (Mat IB; 2019/20) to 46.49% (Stat IA; 2018/19) (Figure 2).

Based on the above findings we consider to be necessary to analyze in more detail the structure of the student's study results, by comparing their results in individual subjects. The students' evaluations can be characterized by means of the average grade, which for all analyzed subjects, except for one exception, was in the interval from 2.22 to 2.37, which should also be completed with the characteristic of variability. Both basic descriptive characteristics are shown in Table 2.

Table 2 Average grades and variability in individual subjects

Academic	Mathematics IA		Mathematics IB		Statistics IA		Statistics IB		Academic
year *	average	st.dev	average	st.dev	average	st.dev	average	st.dev	year *
17/18	2.24	0.69	2.37	0.74	2.43	0.51	2.22	0.55	18/19
18/19	2.35	0.73	2.35	0.72	2.32	0.55	2.25	0.61	19/20
19/20	2.30	0.76	1.82	0.71	2.26	0.73	2.24	0.73	20/21

* Students completed Mathematics IA, IB in the academic year listed in the left column and Statistics IA, IB in the following academic year, which is listed in the right column.

The number of students is sufficiently large to apply the ANOVA method to compare the average evaluation whose results are shown in Table 3.

Table 3 Comparison of students' successfulness in subjects

Study subject	Test statistic	*p-value*
Mathematics IA	1.247	2.88E-01
Mathematics IB	41.046	1.55E-17
Statistics IA	5.455	4.48E-03
Statistics IB	0.090	9.14E-01

Based on the comparison of evaluations of individual students by applying the variance analysis as a basic method for comparing multiple mean values, we can conclude that there is no statistically significant difference in evaluations of students in the subjects Mathematics IA and Statistics IB in compared periods. In the case of Mathematics IB and Statistics IA, we can state that there is a statistically highly significant difference in the marks awarded to individual students. This difference, in the case of Mathematics IB, is caused by achieving excellent results by students (mode A(1)) in the academic year 2019/20 confirmed by Scheffe's test of contrasts, where the values of the test characteristics for the pair comparisons containing this academic year take on a value higher than the critical (Table 4).

Table 4 Results of Scheffé's contrast tests for the subject Mathematics IB

Compared periods	Test statistic	Critical value
2017/18 vs. 2018/19	0.013	0.168
2017/18 vs. 2019/20	0.544	0.165
2018/19 vs. 2019/20	0.531	0.171

In a similar way we examined the results of students from the subject Statistics IA, where the existence of a difference in evaluation for the academic years 2018/19 and 2020/21 was confirmed (Table 5).

Table 5 Results of Scheffé's contrast tests for the subject Statistics IA

Compared periods	Test statistic	Critical value
2018/19 vs. 2019/20	0.114	0.143
2018/19 vs. 2020/21	0.188	0.141
2019/20 vs. 2020/21	0.074	0.145

CONCLUSIONS

In the monitored years 2017-2021 we confirmed only minimal differences in the grades awarded to students in the subjects Mathematics IA, IB and Statistics IA, IB. Statistically confirmed differences in evaluation were in the summer semester of the academic year 2019/20, in which more than a third of teaching and knowledge verification was carried out online. Similarly, the results of the comprehensive evaluation in the subject Statistics IA in

the academic year 2020/21, which are statistically significantly different from the results in 2018/19, are a consequence of online teaching throughout the winter semester.

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