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Original Paper

Mathematical competencies of students entering university studies. Case study of Slovakia

Janka Drábeková*, Tomáš Pechočiak, Vladimír Matušek

Slovak University of Agriculture in Nitra, Faculty of Economics and Management, Department of Mathematics, Slovak Republic

ABSTRACT

The main objective of this paper is the analysis of students' math competences via results of the mathematical experiences of students of SAU in Nitra at the beginning of winter term before the graduation of subject "Mathematics" at the different study programs. We performed a test consisted of 5 tasks. We used the National Educational Program Mathematics ISCED 2, ISCED 3A. We have compared the results of tests of respondents and determined whether the differences between study outcomes of students are significant. Our research has examined the impact of gender, type of secondary school and the grade point in mathematics from secondary school to use mathematical tools to solve tasks according ISCED 2, ISCED 3A. The obtained indices of successfulness show a beneficial effect of male gender and graduated secondary grammar school.

KEYWORDS: university students, mathematical competencies, ISCED 3A, Slovakia

JEL CLASSIFICATION: B74, D35, K40

INTRODUCTION

The Slovak University of Agriculture in Nitra with its educational, scientific and research activities represent the significant part of a European and world educational area. It has become a modern open university which reflects current needs in agri-food sector in a local and global scale. Its mission is to prepare competitive specialists for all areas of agri-food sector as well as other fields of national economy – engineering, finance, institutions and bodies of state administrations and others. It has six faculties providing wide range of knowledge in the field of natural, economic, technical and social.

One of the biggest challenges that higher education faces is preparing today's students to meet future workforce demands [1, 3, 8, 18]. As "21st century competencies" are often allowed to creativity, problem solving, critical thinking, communication, collaboration, self-management. Gosselin, Cooper & Bonnstetter [5] said that although these competencies are considered to

* Corresponding author: Janka Drábeková, Slovak University of Agriculture in Nitra, Faculty of Economics and Management, Department of Mathematics, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic, e-mail: janka.drabekova@uniag.sk

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be at the foundation of individual as well as collective success in the work place, employers report substantial deficiencies in these applied skills. As a result, business leaders and educational organizations are calling for new education policies that target the development of broad, transferable skills and knowledge.

Mathematical competencies

Országhová & Horváthová [14] said that in the contemporary society the university education is the important factor for employment opportunities on the labor market. Our society needs well educated population and broadly qualified work force, all of whom are able to activate mathematical knowledge, insights, and skills in a variety of situations and contexts [11]. The growing role of science, mathematics and technology in modern life requires that all adults, not just those who aspire to scientific careers, become mathematically, science and technology literate [7]. Nevertheless, the student's interest in educational programs with a strong mathematical component is still smaller. Niss [10] said that this is reflected in the so called "relevance paradox": Even though mathematical knowledge is highly relevant in and to society, many, if not most, people have increasing difficulty at seeing that mathematics is relevant to them, as individuals. One thing is to know how to calculate the math, the second thing is to understand it, or apply it correctly and interpret current real life situations, encountered, for example, while reading a magazine about health or agriculture. One of the main aims of mathematical education as such is preparing the students for dealing effectively with the real-life situations [17]. The current task of teachers should be – to keep the students' interest in these subjects and show the importance of applying of acquired competences from mathematics [13].

Competencies and learning outcomes are two related educational terms. Competencies are combinations of attitudes, skills and knowledge that students develop and apply for successful learning, living and working. Competencies help students draw and build upon what they know. Competencies describe the desired knowledge, skills, and behaviors of a student graduating from a program or completing a course or level of education. Learning outcomes describe exactly what a student will be able to do in some measurable way. There may be more than one measurable outcome defined for a given competency. Thus, learning outcomes are the basis for an assessment program.

Mathematical competence means the ability to understand, judge, do, and use mathematics in a variety mathematical contexts and situations. Factual knowledge and technical skills are necessary, but certainly not sufficient, prerequisites for mathematical competence. Debrenti [4] said that mathematical competence encompasses the development and use of skills and abilities related to mathematical reasoning. Which mathematical competencies need to be developed with students at different stages of the education system?

Niss [9] identified eight competencies which form two groups. The first group of competencies is to do with the ability to ask and answer questions in and with mathematics: thinking mathematically, posing and solving mathematical problems, modelling mathematically (i.e. analysing and building models), reasoning mathematically. The other group of competencies is to do with the ability to deal with and manage mathematical language and tools: representing mathematical entities (objects and situations), handling mathematical symbols and formalisms, communicating in, with, and about mathematics, making use of aids and tools (IT included).

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The OECD PISA [12] indicated the following eight components of mathematical competence: reasoning, making deductions; argument and elaborating a proof; communication; modelling; finding solutions; representation; using symbolic, formal and technical language and operations; using mathematical tools.

According the Slovak state educational program, ISCED 3A [2], studying mathematics in secondary school contributes to the development of following key competencies of students:

- competence to apply the basis of mathematical thinking and basic knowledge of science and technology,
- competence to solve problems,
- competence in the field of information and communication technologies,
- competence for lifelong learning - learning to learn,
- social communication competencies,
- social and personal competencies,
- working skills,
- competences for initiative and entrepreneurship,
- competences to perceive and understand culture and to express themselves with the tools of culture.

The educational content of the mathematics, ISCED 3A, is divided into five thematic areas [2]:

- numbers, variables and arithmetic operations,
- relationships, functions, tables and diagrams,
- geometry and metric system of measurement,
- combinatorics, probability and statistics,
- logic, reasoning, making deductions, argument and elaborating a proof.

According Pietriková, Hornyák-Gregáňová & Orlíková [16] students in lower levels of educations should adopt the required education strategy so their education was the most effective, because currently it is not only about adopting the knowledge but as well as the creation and utilization of general abilities and concrete and effective techniques used for learning which can be transferred to the outside of educational environment.

The Intersegmental Committee of Academic Senates (ICAS), representing the academic senates of the three segments of California's higher education system, produced document which includes essential areas of focus for all entering college students in their country. In this document is a summary of the mathematical subjects that are an essential part of the knowledge base and skill base for all students who enter higher education. Students are best served by deep mathematical experiences in these areas [6]:

- Variables, Equations, and Algebraic Expressions: Algebraic symbols and expressions; evaluation of expressions and formulas; translation from words to symbols; solutions of linear equations and inequalities; absolute value; powers and roots; solutions of quadratic equations; solving two linear equations in two unknowns, including the graphical interpretation of a simultaneous solution.
- Families of Functions and Their Graphs: Applications; linear functions; quadratic and power functions; exponential functions; roots; operations on functions and the corresponding effects on their graphs; interpretation of graphs; function notation; functions in context, as models for data.
- Geometric Concepts: Distances, areas, and volumes, and their relationship with dimension; angle measurement; similarity; congruence; lines, triangles, circles, and their

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properties; symmetry; Pythagorean Theorem; coordinate geometry in the plane, including distance between points, midpoint, equation of a circle; introduction to coordinate geometry in three dimensions.

- Probability: Counting (permutations and combinations, multiplication principle); sample spaces; expected value; conditional probability; independence; area representations of probability.
- Data Analysis and Statistics: Presentation and analysis of data; measures of center such as mean and median, and measures of spread such as standard deviation and interquartile range; representative samples; using lines to fit data and make predictions.

The Slovak state educational program ISCED 3A consist the same areas. So we agree that areas listed above should be an essential part of the knowledge base for all students who enter university education.

MATERIAL AND METHODS

The examined sample consisted of 218 students from three faculties of the Slovak University of Agriculture in Nitra (SAU). We selected the Faculty of Economics and Management (FEM), the Faculty of European Studies and Regional Development (FESRD) and the Faculty of Horticulture and Landscape Engineering (FHLE). The examined sample consisted of first-year students of the university, 68 graduated from secondary grammar schools (SGS), and 150 graduated from secondary vocational colleges (SVC, technical, chemical, agricultural or business). The sample structure is shown in Table 1.

Table 1 Numbers of students participating in research

	SGS		SVC		Total
	Women	Men	Women	Men	
FEM	13	22	62	20	117
FESRD	7	6	16	9	38
FHLE	9	11	29	14	63
Total	29	39	107	43	218

We performed a test consisted of 5 tasks. We used the National Educational Program Mathematics ISCED 2, ISCED 3A. The tasks were focused on the algebraic symbols and expressions, rational numbers, solutions of linear equations and inequalities, solutions of quadratic equations, linear functions. Students solved the test in 20 minutes. The maximum number of points that a student could get was 15 points in Test A and Test B.

We utilized basic methods of descriptive statistics and hypotheses testing in the assessment of survey results: test for normal distribution, z-test, analysis of variance (single factor). Statistically verifiable existence of difference in the assessment was reviewed on the base of significance of testing characteristic (p-value), what presents the error probability which we will commit if we reject H0 tested hypothesis even in fact it is valid [16]. In case the p-value of testing characteristic is lower than 0.05, the null hypothesis about the equality of observed features is rejected and the difference in values of statistical feature is considered as statistically significant [15]. We tested the following hypotheses:

- H0: There in no dependence between the test results of students and the type of attended secondary school.
  H1: There is dependence between the test results of students and the type of attended secondary school.
- H0: There in no dependence between the test results of respondents and respondents' gender.
  H1: There is dependence between the test results of respondents and respondents' gender.
- H0: The effects of all levels of factor grade point in mathematics from secondary school (1, 2, 3, 4) are zero, insignificant.
  H1: The effect at least one *i* – level of the factor is significantly different from zero.

We used the program Microsoft Excel 2013 and SAS for the realization of calculations and determination of critical values.

RESULTS AND DISCUSSION

Survey subject was to determine the mathematical experiences of students in SAU in Nitra at the beginning of winter term before the graduation of subject "Mathematics" in areas listed above. For the purpose of determination of respondents mathematical experiences level the survey was realized on the first lesson. In Table 1 the educational respondent structure is presented where 68.81% of all students graduated the specialized secondary school (SVC) like business or hotel academy where as regards the school type we assume the graduation of mathematics with planned types 1 or 2 hour weekly. Other students (31.19%) graduated gymnasium (SGS) with mathematics education 3 or 4 hour weekly. Both types of secondary schools are managed by the Slovak state educational program ISCED 3A.

The results of basic methods of descriptive statistics are presented in Table 2 and an accurate representation of the distribution of numerical data on figure 1.

Table 2 Descriptive statistics

Mean	Standard Error	Median	Mode	Standard Deviation	Kurtosis	Skewness	Range	Count	Confidence Level (95%)
5.23	0.22	5	5	3.30	-0.39	0.43	15	218	0.44

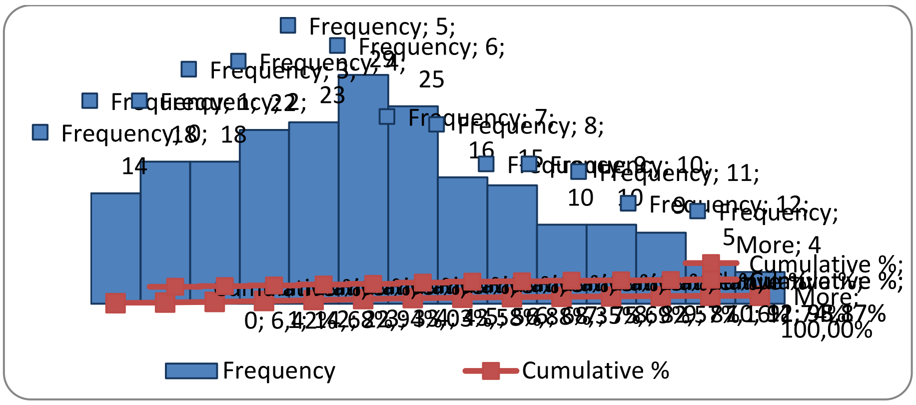

Figure 1 Histogram

Normality test was used to determine if a data set is well-modeled by a normal distribution. We detected a goodness of fit of a normal model to the data.

If we compare the test results of students in accordance with the type of attended secondary schools we find out that the students of special secondary school (SVC) obtained lower mean of points with lower variance. Based on the results of test we can assume the existence of statistically verifiable difference in mathematical knowledge of students of various types of secondary schools. We verified the validity of described hypothesis by z-test. The results are presented in Table 3. The students of gymnasium obtained significantly higher score.

Table 3 z-Test two sample for means of type secondary school

	SGS	*SVC*
Mean	6.73	4.51
Known Variance	13.41	8.24
Observations	68	150
z	4.41	
P(Z<=z) two-tail	0.00001	
Z Critical two-tail	1.96	

When testing two sexes for equality of points mean, the null hypothesis under test is that the results both gender are equal. After random samples are taken from each of the two sexes, were calculated the difference between them and this difference was used to accept or reject the null hypothesis. We detected large difference, so the null hypothesis is rejected. The results are presented in Table 4. The women obtained significantly lower score.

Table 4 z-Test two sample for means of gender

	Female	*Male*
Mean	4.85	5.78
Known Variance	9.75	12.29
Observations	136	82
z	-1.97	
P(Z<=z) two-tail	0.048	
Z Critical two-tail	1.96	

Analysis of variance was used to analyze the differences among group means in a sample. We studied the effect of different levels of grade in math from secondary school (1, 2, 3, 4) on result test. The null hypothesis assumed the same effect, insignificant difference.

Table 5 Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
1	20	154	7.70	10.01
2	65	373	5.74	11.05
3	99	501.5	5.07	9.40
4	34	105.5	3.10	7.63

Table 6 One-way ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	295.15	3	98.38	10.17	0.000003	2.65
Within Groups	2070.47	214	9.68			
Total	2365.62	217				

Table 6 summarizes the calculations needed to test the equality of several grade in mathematics means using analysis of variance. As shown in Table 6, the *between* method of estimating sigma produces a value of 98.38, whereas the *within* method estimate is 9.68. The F ratio indicates that the *between* method estimate is 10.17 times the *within* method value. The calculated *F value* of 10.17 is larger than the critical value (2.65), which means there is enough sample evidence to reject the null hypothesis. The *p-value* indicates that the probability of obtaining an *F value* greater than 10.17 by chance alone is 0.000003. We detected significantly differences in results of respondents according grade in mathematics from secondary school.

CONCLUSIONS

The level of mathematical education depends on many factors and its results are among other things the outcome of the subjective approach of each student to study the subject of mathematics. On the basis of our results, we can state that our respondents had a low ability to use mathematical apparatus, which is an important prerequisite for their professional growth and application. The research results pointed out the weaknesses that could be caused by the preference of the studied thematic areas on different type of secondary schools. Both types of researched secondary schools are managed by the Slovak state educational program ISCED 3A but with different number of lessons per week. We detected significant higher score of students graduated secondary grammar school. The women obtained significantly lower score than men. We detected significantly differences in results of respondents according grade in mathematics from secondary school. The effect at least one i – level (1, 2, 3, 4) of the factor grade point in mathematics from secondary school was significantly different from zero.

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