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Didactic notes on solving probability tasks using MS Excel tools

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ABSTRACT

The goal of mathematics education of future economists is the acquiring skills and mastering logical procedures, which will ensure the correspondence of professional qualities with the requirements for expertise of graduates. The demands for creative and systematic thinking, independent and innovative proposals in solving practical problems are coming to the fore. The aim of this contribution is to present options of MS Excel tools in the teaching and active study of the thematic unit of probability theory. Mathematical methods and formulas with sequences and repeated types of calculations, can be presented to students through program tools of MS Excel. The paper contains examples of the usage of Excel built-in functions to calculate problems from classical probability, which can be applied for development of students' logical thinking via solving tasks. The application of MS Excel tools in calculations belongs to the educational process, while it is the effective component for the improvement of students' knowledge, presentation of logical procedures and mathematical principles of solving tasks.

KEYWORDS: mathematical problems, combination number, classical definition of probability, MS Excel

JEL CLASSIFICATION: I20, I23

INTRODUCTION

Information technologies have become an important part of education at universities and their tools are used in various ways directly in education as well as in the independent study. The process of mathematics education uses not only traditional methods but also tools of information technology, computer and graphic software. A successful process of learning mathematics is also linked to information literacy and relevant information competences [16]. The European Commission defines key competences as follows: “Key competences are a transferable and multifunctional set of knowledge, skills and attitudes that every individual

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needs for his or her personal fulfilment and development, for participation in society and for successful employment” [7].

In the training of economists and managers, exact methods have a long-standing presence within mathematical subjects. Graduates are required to be flexible in their thinking and to have independent decision-making skills for integrating into the management and marketing of an enterprise in their future profession. Results of the study on mathematical knowledge pointed to weaknesses that could be due to the differences of studied subject areas in various types of secondary schools [5]. Only minimal differences in exam grades in the study subjects Mathematics IA, Mathematics IB and Statistics IA, Statistics IB were confirmed in the years 2017-2021. When comparing the average exam grade in mathematics subjects over a period of several years, the results showed that the average grade progressively deteriorates [8].

Correct solving of mathematical task is based on understanding the mathematical terminology and applying the mathematical method. The main aim of the paper is to present the use of selected MS Excel tools in teaching the thematic unit of probability theory. In addition to direct calculations, we can use MS Excel tools to:

- Creation of seminary projects and their variation,
- Creating assignments for written tests and exams for larger number of students,
- Checking the correctness of problem solving,
- Presentation of formulas and calculations,
- Repeated calculations in type assignments, etc.

The development of mathematical skills in the era of information and communication technologies is also realized with the use of games, which can be designed to engage learners more in the learning process and the objects and settings of the game can be further developed [9]. Computer-assisted learning brings new methods and forms to the teaching process, thus modernizing it and making it more attractive. In solving mathematical problems and their presentation, it is necessary to edit mathematical formulas that students learn while solving problems in MS Excel [1]. Mathematical and statistical calculations involve exact procedures that can be performed using MS Excel tools, while the user does not need to have detailed mathematical or programming knowledge [4], [10].

As Ďuriš and Šumný [6] state, the MS Excel environment is suitable for solving a wide range of mathematical problems, helping to develop students' logical abilities, which are interrelated and intertwined in the exact disciplines. The knowledge acquired by solving tasks in the MS Excel can be further applied by students in the processing of experimental data and research results, which they carry out as part of semester projects, bachelor's or master's diploma theses in various fields of study [14].

Morales et al. [12] investigated the level of students' knowledge in the context of virtualization of education, which may lead to some students' lack of understanding of large-scale mathematical calculations during task solving. In the results of the research study, it was demonstrated that the implementation of Excel software as an additional tool of study can facilitate the understanding of the mathematics education curriculum and increase the interest in learning.

The Visual Basic Application for Excel used in mathematics teaching can develop students logical, creative and analytical thinking skills [2]. The availability of IT tools requires constant changes in the content and methodology of the educational process in relation to the

young generation, for whom competences for working with information are essential [11]. The creation of modules that support the development of skills such as IT, communication and presentation support the study of mathematics and mathematical methods in various fields of study [3].

MATERIAL AND METHODS

Using the apparatus and methods of probability theory, it is possible to mathematically express experiments and trials that lead to different results even under unchanged conditions. The issue of probability theory forms the basis for the study of mathematical statistics, analysis in estimation theory, statistical hypothesis testing, stochastic modeling, etc.

The main material for this paper was obtained from didactic research at the Faculty of Economics and Management (FEM), the Slovak University of Agriculture in Nitra. The thematic area of the basics of probability is included in the compulsory study subject Mathematics IB. The subject is taught in the summer semester of the 1st study year first year of the bachelor's degree at the FEM faculty. The content of this part includes topics from combinatorics and probability, which students solve on the exam. Data for short analysis were obtained from the teaching and examination tests in the subject Mathematics IB.

We focused the didactic purpose on selected tasks that use a combination number and probability calculation using the classical definition of probability [13]. The basic formula (combination number) is used to calculate combinations of the k -th class from n elements without repetition.

Main terms used in probability problems:

Formula for combinations of the k -th class from n elements without repetition:

$$C_k(n) = \binom{n}{k} = \frac{n!}{(n-k)!k!},$$

where n is the total number of elements in a given set, k is the number of selected objects (the order of the objects is not important), symbol ! (exclamation mark) means factorial.

Classical definition of probability (formula):

$$P(A) = \frac{m}{n},$$

where $P(A)$ is probability of a random event A , m is the frequency or the number of favorable outcomes, n is the number of total possible outcomes.

Another important element of probability problems is the correct understanding of the following mathematical formulations: exactly 1, exactly 2, at most 1, at most 2, at least 1, at least 2, etc. Mentioned formulations occur in tasks with the selection of the specified number of elements with the given property. In solving task, students compile combination numbers for the given selections of elements and then have to find out the probability of a random event via the classical definition of probability. Samples of calculations in MS Excel are presented in the following part.

RESULTS AND DISCUSSION

Nowadays, students have access to software and programs that will solve a mathematical problem without the task giver mastering additional details of mathematical theory. The goal of teaching mathematics is to master the main concepts by students, acquire calculation skills and be able to apply the achieved knowledge. The study groups include students from different high schools, so they have a different level of knowledge in high school mathematics.

Examples of combinations calculation

In this part, there are presented tasks that students in the Mathematics IB study subject solve using mathematical methods. Study aim is to learn the logical procedure for solving task and the necessary mathematical adjustments of combination numbers. Subsequently, we will show the scheme of solving the task using MS Excel spreadsheet tools, which will enable students to better understand this topic.

Task 1: Calculate the combination number $\binom{6}{2}$.

a)	$\binom{6}{2} = \frac{6!}{4! \cdot 2!} = \frac{6 \cdot 5 \cdot 4 \cdot 3 \cdot 2 \cdot 1}{4 \cdot 3 \cdot 2 \cdot 1 \cdot 2 \cdot 1} = \frac{30}{2} = 15$	whole calculation of the factorials
b)	$\binom{6}{2} = \frac{6!}{4! \cdot 2!} = \frac{6 \cdot 5 \cdot 4!}{4! \cdot 2 \cdot 1} = \frac{30}{2} = 15$	reduced factorial calculation
c)	Formula (function COMBIN) in Excel =COMBIN(6;2)	result 15

In the part c) we present solution via COMBIN function built-in MS Excel: calculation of combinations k -th class from n elements without repetition, $k = 2$, $n = 6$. The COMBIN function in MS Excel returns the number of combinations without repetition for a given number of items. The command notation for calculating combinations without repetition is =COMBIN(number; number_chosen).

Task 2: Calculate the value of the fraction $\frac{16!}{13!}$.

a)	$\frac{16!}{13!} = \frac{16 \cdot 15 \cdot 14 \cdot 13!}{13!} = 16 \cdot 15 \cdot 14 = 3360$	presentation of factorials
b)	$\frac{16!}{13!} = 16 \cdot 15 \cdot 14 = 3360$	reduced calculation

Presented calculations are used in type tasks, so it is necessary for students to master them.

Examples of probability calculation using MS Excel

In the solution of the following task, we will present the scheme for solving type tasks about combinations and probability using MS Excel tools. Task is concentrated on mathematical formulation “at most one”, “at most two”.

Task 3: There are 22 students in a class, of which 8 passed with honors and 14 passed without honors. We will randomly choose 5 students. What is the probability that among chosen students:

- there will be at most one student without honors – $P(A)$,
- there will be at most two students without honors – $P(B)$.

Solution to task 3a):

In order to have a different notation of the values in the used formulas, we use the following notation for the classical probability:

$$P(A) = \frac{M}{N},$$

where M is the frequency or the number of favorable outcomes, N is the number of total possible outcomes.

The number of all options for choosing 5 students out of 22 is the combination number:

$$N = \binom{22}{5}$$

The number of all options for selecting at most one student without honors is as follows:

$$M = \binom{14}{0} \cdot \binom{8}{5} + \binom{14}{1} \cdot \binom{8}{4}$$

Probability that among selected students there will be at most one student without honors is:

$$P(A) = \frac{M}{N} = \frac{\binom{14}{0} \cdot \binom{8}{5} + \binom{14}{1} \cdot \binom{8}{4}}{\binom{22}{5}} = \frac{56 + 980}{26334} = 0.0393408$$

The aim of this task is to understand:

- Formula for combinations without repetition,
- Meaning of the mathematical formulation: select at most one element with the given property,
- Find the number of total possible outcomes N ,
- Evaluate the frequency or the number of favorable outcomes M .

Table 1 shows steps of the task solution in MS Excel using the COMBIN function.

These logical steps are also used in the solution of the task b.

Table 1 Scheme for calculating the probability in MS Excel in task 3a)

Calculation of N - combinations without repetition					
	value	function	=COMBIN(n;k)		formula with references to cells
n =	22	calculation	=COMBIN(22;5)		calculation =COMBIN(D6;D7)
k =	5	result $N =$	26334		result $N =$ 26334
At most 1: we choose at most one element with the given property					
n1 =	14	function			=COMBIN(n1;k1)
k1 =	0	calculation			=COMBIN(14;0)
		result 1			1
n2 =	8	function			=COMBIN(n2;k2)
k2 =	5	calculation			=COMBIN(8;5)
		result 2			56
		product 1 = result 1 * result 2			56
		function			=COMBIN(n1;k1+1)
		calculation			=COMBIN(14;1)
		result 3			14
		function			=COMBIN(n2;k2-1)
		calculation			=COMBIN(8;4)
		result 4			70
		product 2 = result 3 * result 4			980
		Probability $P(A) =$	$(56 + 980)/26334 =$		0.0393408

Source: author's calculation

Solution to task 3b):

We will use the result for the number of all options for choosing 5 students out of 22 from the Table 1. Again, it is necessary to find out the number of all options for selecting at most two students without honors. Subsequently, it is possible to express the probability that among the selected students there will be at most two students without honors:

$$P(B) = \frac{\binom{14}{0} \cdot \binom{8}{5} + \binom{14}{1} \cdot \binom{8}{4} + \binom{14}{2} \cdot \binom{8}{3}}{\binom{22}{5}} = \frac{56 + 980 + 5096}{26334} = 0.199021$$

Table 2 shows example of the scheme for calculating individual combination numbers and, subsequently, the probability of phenomenon B in MS Excel using the result from Table 1.

Table 2 Scheme for calculating the probability of a phenomenon in MS Excel in task b)

At most 2: we choose at most two elements with the given property				
n1 =	14	function		=COMBIN(n1;k1)
k1 =	0	calculation		=COMBIN(14;0)
		result 1		1
n2 =	8	function		=COMBIN(n2;k2)
k2 =	5	calculation		=COMBIN(8;5)
		result 2		56
	product 1 = result 1 * result 2			56
		function		=COMBIN(n1;k1+1)
		calculation		=COMBIN(14;1)
		result 3		14
		function		=COMBIN(n2;k2-1)
		calculation		=COMBIN(8;4)
		result 4		70
	product 2 = result 3 * result 4			980
		function		=COMBIN(n1;k1+2)
		calculation		=COMBIN(14;2)
		result 5		91
		function		=COMBIN(n2;k2-2)
		calculation		=COMBIN(8;3)
		result 6		56
	product 3 = result 5 * result 6			5096
Probability P(B) =		(56 + 980 + 5096)/26334 =		0.2328549

Source: author's calculation

We can also use the mentioned procedure to solve other types of tasks in the MS Excel environment.

Score in solving probability tasks

In the Table 3 there are summed up students' results of solving probability tasks. The file was created by 1st-year students at the Faculty of Economics and Management who passed exam from the Mathematics IB study course in the academic years 2022/2023 and 2023/2024. Results in percentage show that students achieved better results in the year 2022/2023 in all evaluated parts. We can rate the overall success in solving task as low (56% in academic year

2022/2023, and 49% in year 2023/2024). One of reasons is that students have gaps in the practical implementation of calculations and numerical errors often occur in the solutions.

Table 3 Students achievements in solving probability problems

Task and parts of the solution	Year 2022/2023	
	Number of students	Number of students with correct solution (absolute / in %)
Calculation of the combination number	52	39 (75%)
Probability calculation	52	32 (62%)
Overall success in solving the task	52	29 (56%)
Year 2023/2024		
Calculation of the combination number	43	29 (67%)
Probability calculation	43	23 (54%)
Overall success in solving the task	43	21(49%)

Source: author's calculation

Students use traditional calculator for numerical calculations. Calculations for multiplying or dividing whole numbers are also facilitated by math function in MS Excel program. Tasks with this application of built-in functions enable the development of logical thinking and finding task solution with subsequent steps. Students at FEM will use acquired knowledge in the study of other subjects, e.g. Basics of probability theory, Mathematical statistics and others [15]. The presented results can be applied in the teaching process and students can utilize computing skills in other subjects as well in practical life. As stated by Voogt et al. [17] an important prerequisite for the application of IT tools in education is the professional development of teachers who know suitable application and use it in the teaching process.

CONCLUSIONS

Information technology tools offer various possibilities for their application in contact teaching, individual study and help increase the attractiveness of the educational process at universities. The use of IT and the creation of educational materials of various forms are the part of the pedagogical competences of the mathematics teacher.

In the paper, we presented selected types of tasks from the thematic unit of probability theory, which is included in the content of mathematics subjects at economics faculties. We wanted to show a possible methodological way for solving basic tasks of probability using MS Excel tools. The given solution scheme will bring students closer to the concepts of probability and enable them to better understand the individual steps of the task calculation. Teachers can apply this didactic presentation for the variable creation of tasks.

Information and communication technologies have a significant impact on the way people work and live in today's society. It is necessary to include tools of IT appropriately in the educational process, so that we can increase its efficiency and stimulate the internal motivation of students. By solving tasks using MS Excel, students consolidate their

knowledge of mathematics and acquire a positive attitude towards mathematics and interesting application possibilities.

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