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*Original Paper*

Outcomes of distance education in Mathematics at secondary technical school: a case study

Dana Országhová^{1*}, Dana Žiaková²

¹ Slovak University of Agriculture in Nitra, Faculty of Economics and Management, Institute of Statistics, Operation Research and Mathematics, Slovak Republic

² Secondary Technical School of Civil Engineering in Žilina, Žilina, Slovak Republic

ABSTRACT

Education at secondary vocational schools has an important role in preparing graduates to perform professional activities in practice. These schools provide a complete secondary education, and Mathematics is also a part of the study plan. In this paper, we focused on the success of students in solving selected types of mathematical problems during the school year 2020/2021, when the study process at secondary schools was carried out in a distance form. The main goal was to evaluate the mathematical knowledge of the secondary school students through a set of selected tasks. The research sample consisted of 21 students of the 3rd year of the secondary technical school with a focus on civil engineering study program, for which we analyzed tasks of online tests in the first and second half of the school year. Using methods of mathematical statistics, we compared and evaluated the success of students in solving problems that were part of the tests from the mathematics curriculum. The results show that students have mastered the necessary electronic tools and methods of distance learning in acquiring mathematical knowledge.

KEY WORDS: mathematics education, secondary technical school, sequences, combinatorics, probability, Wilcoxon signed-rank test

JEL CLASSIFICATION: D40, C50, M10

INTRODUCTION

Education is one of the important factors for the development and quality of human resources, that are key for the knowledge society and the economy of society. The interest in vocations of children (or pupils) in primary schools is gradually evolving and changing, among other

* Corresponding author: doc. RNDr. Dana Országhová, CSc., Institute of Statistics, Operation Research and Mathematics, Faculty of Economics and Management, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, e-mail: dana.orszaghova@uniag.sk

things because new professions are emerging depending on changes in society. After completing primary education, students decide at which secondary school to continue education, and this choice is conditioned by the interest in the profession they want to do in adulthood. In the Slovak Republic the system of secondary education is governed by the *Act on Education* (School Act) [1], which lists in § 32 the following types of secondary schools in the Slovak Republic: a) Grammar school, b) Secondary vocational school, c) Secondary sports school, d) School of the Arts Industry, e) Conservatory.

Educational institutions, and thus secondary schools, are an important factor in the development of each region and provide conditions for linking education and the needs of the labor market in each region. As stated in the *National Program for Learning Regions* [5]: "strong links need to be established between educational institutions, educational establishments, higher territorial units and municipalities, employers and professional associations".

The aim of the educational process at a secondary vocational school is the quality preparation of pupils for practice and other forms of study. Secondary vocational schools are focused on the development of practical skills and the creation of conditions to support the activity form of teaching. In addition to professional subjects, students also have general education subjects in their study plan. Complete secondary vocational education is finished by successfully passing the school-leaving examination. Graduates of a secondary vocational schools can continue their study at universities.

During the school years 2019/2020 and 2020/2021, the course of education at all levels was influenced by the coronavirus pandemic. In 2020, schools were closed in the Slovak Republic to protect students and teachers from COVID-19, and teaching was moved to online space with the support of information technology (IT) tools. Instructions for secondary schools were issued at the Ministry and the „Decision“ of the Minister of Education, Science, Research and Sport of the Slovak Republic [3] showed “with effect from October 12, 2020 until the appeal, the decision as follows: a) exceptionally interrupts school teaching in secondary schools pursuant to § Section 32 of the Education Act, with the exception of school teaching in the first to fourth years of the eight-year secondary school curriculum; secondary school directors will provide distance education for secondary school students”. Teaching at secondary schools took place from mid-October in the school year 2020/2021 in distance form. After the improvement of epidemic conditions, the entry of secondary school students in 2021 was determined in April, first for the graduation years, and then in May also for students from the 1st to the 3rd school year.

The transition from full-time contact study to distance learning has brought many changes for teachers in organizing the educational process, as well as for students who have had to start using IT tools to join on-line teaching and perform the required educational tasks. As Turek [11] states “during the distance learning, the following principles of programmed teaching are appropriate for the effectiveness of mathematics teaching: 1) Principle of small steps, 2) Principle of active response, 3) Principle of immediate fixation, 4) Principle of individualization, and 5) Principle of evaluation and improving the teaching process”.

The distance education takes place in a virtual space, where the current young generation gains new experiences, skills, and knowledge. In a research study [2], authors analyzed five

main topics in the secondary education during the pandemic, including the structure of mathematics content, teachers' readiness for distance learning, psychological and emotional aspects arising during a coronavirus pandemic.

The course of distance education at Slovak primary and secondary schools in 2019/2020 was assessed via a questionnaire survey in which an estimate of the pupils' involvement in this form of education was made. The main findings of this survey include an estimate that 52,000 primary and secondary school pupils (7.5% of the student population) were not involved in distance learning. Approximately 128,000 pupils (i.e. 18.5% of the student population) did not learn online; most of them were probably educated by other forms of distance learning, e.g. through printed worksheets prepared and delivered to them by teachers [4].

The complete secondary vocational education is finished after successfully passing the school-leaving examination in compulsory and optional subjects. Many graduates of secondary vocational schools continue their studies at universities, choosing faculties that correspond to the focus of the completed secondary school. Knowledge from secondary school is the basis for the study of mathematical subjects at the university and the level of knowledge of newly admitted students is examined through an entrance math test. Students motivation is still one of the important determinants of success in university study [6].

In this paper, we focused on mathematical education at secondary vocational schools and its outputs during the period of distance education in the school year 2020/2021. The current network of secondary technical schools (as a kind of vocational schools) in the Slovak Republic was created gradually and has base in industrial enterprises that need qualified workers for special areas of practice. Table 1 contains data on the number of secondary technical schools in the Slovak Republic by region in year 2020.

Table 1. Number of secondary technical schools in the Slovak Republic by region

Region	Number	Region	Number
Bratislavský	6	Žilinský	3
Trnavský	4	Banskobystrický	4
Trenčiansky	4	Prešovský	6
Nitriansky	5	Košický	5
Sum: 37 schools			

Source: [9], author's processing

In the period 2012 - 2017 data of the Statistical Yearbook showed a declining trend in the number of high school graduates in the Slovak Republic; subsequently, in years 2019 and 2020, there was a slight increase [10]. As reported Pechočiak and Drábeková [7], such trend was also reflected in the decline in the number of students enrolled in universities, until a slight increase was recorded in 2018. A part of secondary school graduates continues in study at foreign universities, thus the number of students at Slovak universities deepens every year.

MATERIAL AND METHODS

The motivation to write the paper followed from the distance form of education at secondary vocational schools. We were interested in how students mastered selected topics from the curriculum of mathematical subjects. The logical structure of the curriculum, symbolic notations, abstract considerations and generalizations are used in mathematics. Mathematical relations, graphs and diagrams are basis for acquiring of mathematical knowledge and computational skills. During the distance learning, students needed to be motivated to take an active part in online teaching and to perform assigned individual tasks.

The main goal of this paper was the analysis of the results of mathematical education at a secondary technical school with a focus on the subject matter of the 3rd year of study. The selected research sample was formed of students of the 3rd study year at the Secondary Technical School of Civil Engineering in Žilina. Students of the 3rd study year started full-time teaching again from May 11, 2021.

In the evaluation of students' mathematical knowledge, we focused on the following thematic areas in the 1st and 2nd parts of the school year 2020/2021:

1st half of year: Sequences and their properties, Arithmetic sequence, Geometric sequence.

2nd half of year: Combinatorics and Probability.

We present selected examples to individual topics in the analyzed tests.

Test 1. Sequences

Task 1: Write the first five members of the sequence $\left\{\frac{n-1}{n+1}\right\}_{n=1}^{\infty}$ and find out if it is bounded.

Task 2: Display the first five members of a sequence $\left\{\frac{n+2}{n}\right\}_{n=1}^{\infty}$.

Test 2. Arithmetic sequence

Task 3: In the arithmetic sequence $a_1 = 23, s_7 = 35$. What is the difference of this sequence?

Task 4: Find the first term and the difference of the arithmetic sequence to which it applies

$$\begin{aligned}a_2 + a_3 &= 2 \\a_2 + a_7 &= -8\end{aligned}$$

Test 3. Geometric sequence

Task 5: Write the first five terms of a geometric sequence if $a_2 = 27, a_3 = 81$.

Task 6: Calculate the quotient of the geometric sequence if $a_3 = \frac{1}{8}, a_5 = 2$.

Test 4. Combinatorics

Task 7: How many different natural five-digit numbers with different digits can be formed using digits 0, 1, 2, 3, 4, 5?

Task 8: There are 30 students in the class, 20% of them boys. How many ways can we choose 4 girls for a trip to Paris?

Test 5. Probability

Task 9: What is the probability of having the sum of 9 after rolling 3 dice?

Task 10: There are 38 students in the class. Just 7 students do not have homework. The teacher randomly checks 8 students. Calculate the probability that no more than three (out of the checked students) have a homework assignment.

In the evaluation of mathematical tasks and tests, the current evaluation scale was used, which is a part of the approved evaluation criteria of study subjects at secondary school (Table 2).

Table 2. Evaluation criteria for Mathematics

Percentage success	Final grade
90 % to 100 %	Excellent (1)
75% to 89.99 %	Very good (2)
50% to 74.99%	Good (3)
33.33% to 49.99%	Sufficient (4)
Less than 33.33%	Insufficient (5)

Source: [8], author's processing

Due to the size of the research sample (21 students), we applied the Wilcoxon signed-rank test (which belongs to the non-parametric statistical tests) to determine the significance of the differences in the mean value between individual tests.

RESULTS

We evaluated 3 tests in Mathematics from the 1st half and 2 tests from the 2nd half in the 3rd year of study in academic year 2020/2021. Each test contained 5 tasks from a given topic and for the correct solution of all tasks the student could get 6 points together. Results of the analysis of tests in the 1st and 2nd part of school year are in Figure 1.

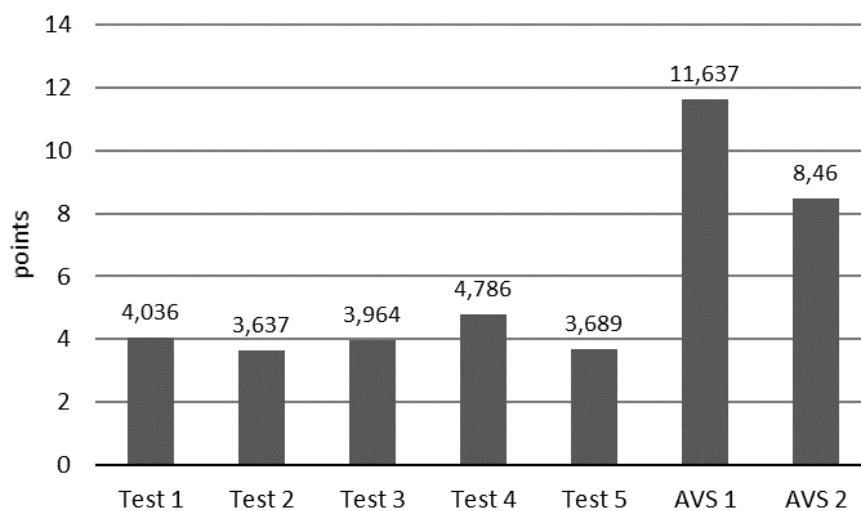


Figure 1. Evaluation of the average point score in the solution of tests

Source: authors

The best average point score was achieved by students in the Test 4 in the 2nd part of school year and the worst average evaluation was obtained by students in Test 2 in the 1st half of the year. The value of AVS 1 expresses the average score for Tests 1 to 3 together. AVS 2 expresses the average number of points for Tests 4 and 5. To compare these data, the average percentage success evaluated for tasks in the first half was 64.7% (AVS 1 recalculated) and for tasks in the second half of the year, the average percentage success rate was 70.5% (recalculated AVS 2).

According to the evaluation scale, we conclude that students managed the analyzed tasks on average grade Good (3). The evaluated tasks are the part of the curriculum in the 3rd year and other thematic tests and students' activities are included in the final semi-annual and end-year evaluation. The resulting average grade from Mathematics in this research sample was 2.77 in the first half of the school year 2020/2021 and 2.33 in the second half of the school year. Students solved tasks better in the 2nd half of the year and they already knew from the 1st half of the study means and methods of distance education.

If we rank all evaluated tasks together according to the assigned grade from 1 to 5 using the evaluation scale, then we obtain the following histogram for all tasks evaluation (Figure 2). In the analyzed sample of tasks, the highest number was achieved by the grade 3 (Good).

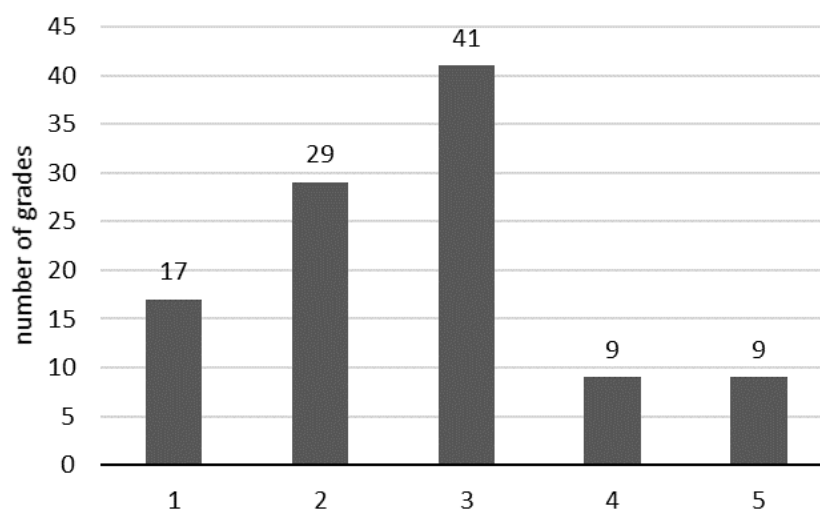


Figure 2. Histogram of grades for all tasks together
Source: authors

If we display the evaluation of success in solving problems according to grades obtained in individual tests, then we see that the problems from Combinatorics in the Test 4 were solved by most students with a grade 1 (Excellent) (Figure 3). This also corresponds to the highest average score of the Test 4. The grade 2 (Very good) was awarded to the most students in assignments on Sequences in the Test 1, which also corresponds to the highest average score of Test 1 in the first half of the year.

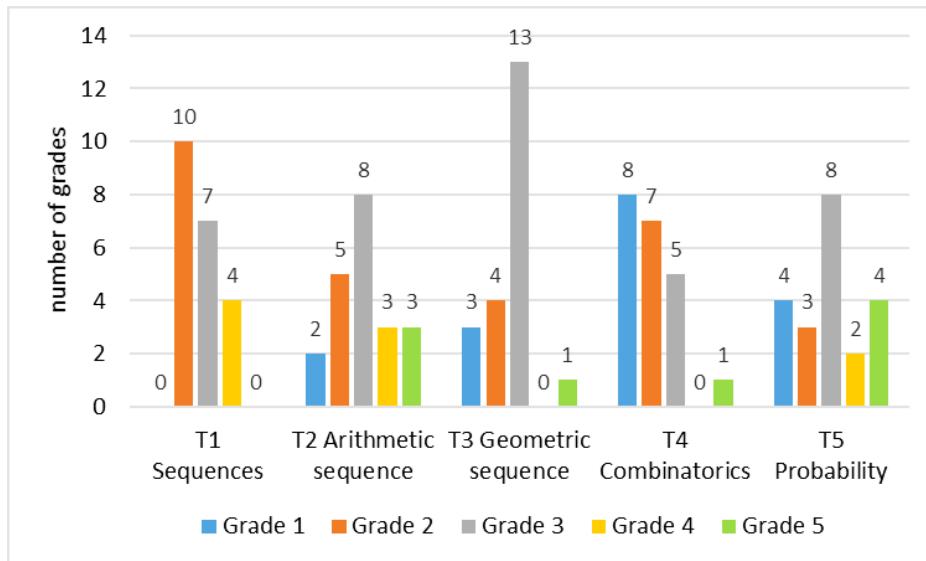


Figure 3. Assessment of tasks according to particular tests
Source: authors

Using the Wilcoxon signed-rank test, we found that there are significant differences in the obtained score of Test 4 and Test 5 at the selected level of significance $\alpha = 0.05$. When testing the average score for the 1st and 2nd half of the school year (AVS 1, AVS 2) there was also confirmed the significance of the differences in the mean value. Using another statistical method - the correlation coefficient - a strong correlation was confirmed between the average score of AVS 1 and AVS 2 (Table 3). This means that students who had good results in the first half of the year tried to gain knowledge and good evaluation in Mathematics in the second half of the year too. There is a moderate relationship between the Test 1 and Test 3, and between Test 4 and Test 5. The other evaluated correlations are weak.

Table 3. Results of Wilcoxon signed-rank test and correlations ($\alpha = 0.05$)

Topic 1	Topic 2	p-value	Correlation
T1 Sequences	T2 Arithmetic sequence	0.29	0.314
T1 Sequences	T3 Geometric sequence	0.92	0.367
T2 Arithmetic sequence	T3 Geometric sequence	0.26	0.266
T4 Combinatorics	T5 Probability	0.008*	0.392
AVS 1	AVS 2	0.000*	0.675

Source: author's calculations

CONCLUSIONS

Secondary vocational schools prepare graduates for professional work and creative activity in their future profession. Some graduates of secondary vocational schools will start their internships and some graduates will continue in study at technical faculties. These faculties

also have mathematical subjects included in their study programs, where students apply and expand the acquired knowledge of high school mathematics.

By analyzing the data of the empirical research, we found the average grade in Mathematics at the level of 2.77 in the first half of the school year 2020/2021; and in the second half of the year, it was 2.33. Using a non-parametric statistical test, it was confirmed the significance in differences between the evaluated tests T4 and T5 in the second half of the school year. In the research sample it was also approved the significance in differences between sum of points together for individual half-years.

During the distance education in 2020/2021, secondary school teachers used modern didactic means, which required their own creative contribution to achieve teaching goals. The realization of the process of mathematical education with the use of IT tools also affects the learning outcomes. In any change in the process of the teaching, the teacher must consider many of direct and indirect factors affecting the course of education.

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