On the Teaching of Natural Science- and Electrotechnologically-Oriented University Course for Future Teachers in the Period of Covid 19 Pandemic

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Abstract—The closure of schools and urgent importance of distance education during the Covid 19 pandemic revealed a necessity to find suitable teaching methods that would help to maintain the continuity level of educational system in case of different possible critical periods of society's survival, such as viral and bacterial pandemics, war, climate, meteorological and other disasters. In this context, the need for possibilities of distance-oriented further education of teachers has also emerged. Moreover, it was very important to create a great amount of suitable teaching materials. All mentioned facts require serious didactic research. In fact, it would also help to identify the positives and negatives of previous teaching methods applied in each individual school subject before the Covid 19 pandemic in Slovakia. During the Covid 19 pandemic, the authors of this paper have implemented a natural science-technologically oriented university course for future teachers in the period of Covid 19 pandemic. The research was conducted by method of pedagogical experiment. Paper consists of 9 chapters altogether, also including introduction, conclusion, acknowledgement, and bibliography. The first chapters are theoretical. They directly present the process of creating FVCOVIDE = Distance forms of education (during Covid 19 pandemic, having the character of experimental forms of teaching). Chapter 3 is of pedagogical experiment nature, applying the above-mentioned models into school practice. It also includes research hypotheses, statistical data processing and results interpretation.

Keywords—Covid 19 pandemic, teaching science, university course, natural sciences, future teachers

1 Introduction

In the beginning, we explain the main terminology related to the topic of this paper. We have chosen a scientific work of Slovak famous methodologist, Ivan Turek, who wrote the book of Didactics, printed by Iura Edition in 2018 [4].

In didactics, contact forms of teaching and learning defines a form of education, during which teachers and their students are "face to face". Online learning is term charactering teaching-learning process taking place in a viral space. Distance education occurs when teacher, students, and classroom are separated, but can communicate through different ways of long-distance approaches. If distance education is organized online in a real-time, then it is called online distance education. Currently, it is possible to teach and learn online distantly by using various types of digital technologies. Finally, E-learning is defined as learning in "electronic space".

During the Covid 19 pandemic, schools were open differently in different countries. There was no universal template that would have determined whether students should have been educated by means of distance education, or they should have returned to the classrooms, or whether something else should have been proposed. At that time, it seemed that the use of both existing educational teaching-learning platforms was an option. They are namely dominant contact platform, which is very pragmatic in its applying into the educational process, but also the online distance platform, which before pandemic, was used more occasionally, mainly in order to increase the economy of teaching. See Figure 1 for terminology and system of abbreviations we used in this research.

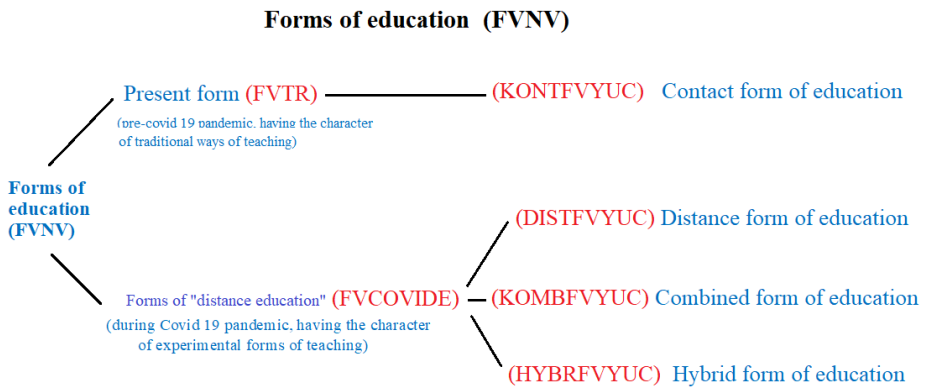

Fig. 1. Forms of education in Slovak educational system—terminology and system of abbreviations

The authors of this paper have already published several research papers dealing with the technological innovations in teaching science-oriented subjects. Results of their previous research can be found for example in [5], [6], [7]. This research paper is unique especially because the mentioned topic of the distance form of teaching had already been investigated on a general didactic level by various authors; however, in this paper it is being examined on a specific didactic level. This means, the paper examines specific didactic phenomena of natural- and technological- character, with an emphasis on elementary physics, biology, ecology and technologies.

2 FVNV (models) for teaching of natural science and technologically oriented university course for future teachers in the period of Covid 19 (abbr. UCNSTP)

In different phases spreading the pandemic, we have implemented (designed and applied) the following FVNV (models) of science-oriented curriculum, hereinafter named by the abbreviation v **UCNSTP:**

A. Contact form (pre-Covid—having the character of a traditional form) of teaching UCNSTP (abbreviation KONTFVYUC)

The KONTFVYUC provided in this research was based on "face to face" principle. It was applied as a teaching method while teaching a specialized university course of UCNSTP (pre-lectures, seminars, laboratory exercises) in the pre-pandemic period in Slovakia. The research data comes from the period: February 1, 2019–February 1, 2020. The realization of KONTFVYUC (creation and application in teaching) is shown schematically in Figure 2.

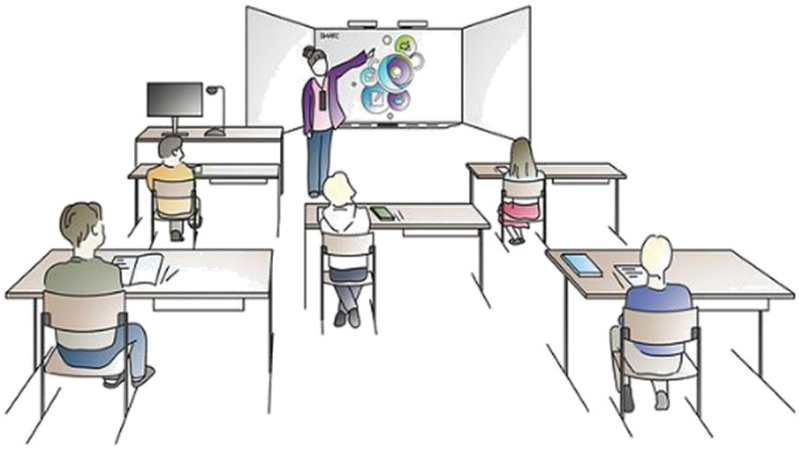

Fig. 2. Design and application of KONTFVYUC—scheme. (illustrated figure [12])

B. Distance form of teaching UCNSTP (abbr. DISTFVYUC)

The distance learning system designed by the authors of this paper is based on the principle of "remote" data transfer on the platform of digital technologies. In this case, lectures, seminars and laboratory exercises were carried out by MS Teams; however, students got us a feedback through MS Forms. The application period of DISTFVYUC of UCNSTP course lasted for one year. It started in the beginning of Covid 19 pandemic, in February 2020 and finished in February 2021. For one year, teachers as submitters,

transmitted the teaching-learning process from the specialized university classroom and the students, in the role of receivers, received the knowledge transmitted through the Internet into their homes of dormitories. The implementation of DISTFVYUC (design and application in teaching) is shown schematically in Figure 3.

Fig. 3. Design and application DISTFVYUC—scheme. (illustrated figure [12])

C. Combined form of teaching UCNSTP (abbr. KOMBFVYUC)

When epidemiological situation was better and schools were open for student again (under strict epidemiological rules, we began to implement—that means, to design and apply KOMBFVYUC. This model of teaching is characterized by the fact that the lectures continued to be held by "distance education", i.e. the distance principles of transfer. We decided to use MS Teams. However, for seminars, laboratory exercises and practicals, contact form of education was preferable. The application period of KOMBFVYUC of UCNSTP course lasted for one year. It lasted from February 2021 to February 2022. Implementation of KOMBFVYUC, its design and application in teaching is shown schematically in Figure 4.

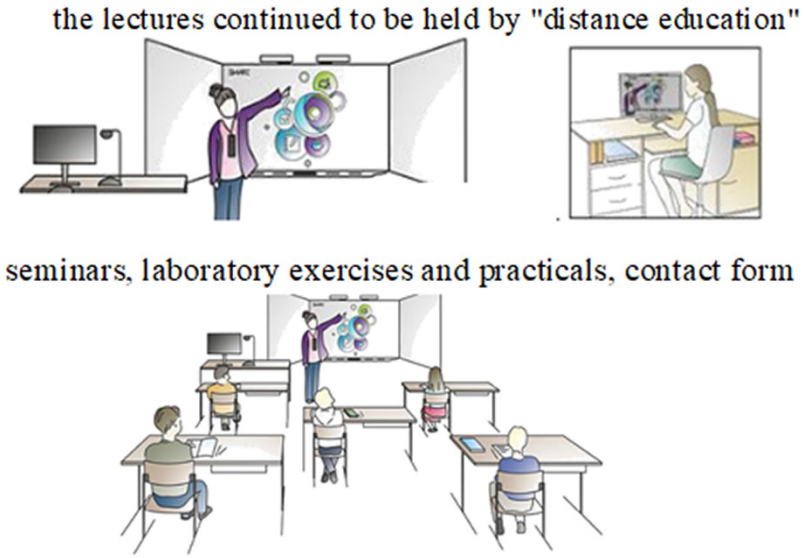

Fig. 4. Design and application of KOMBFVYUC—scheme. (illustrated figure [12])

D. Hybrid form of teaching UCNSTP (abbr. HYBRFVYUC)

With another wave of Covid19 pandemic and the subsequent worsening of the epidemiological situation in the country, general epidemiological rules were getting stricter and stricter. For this reason, personal presence of students in the classroom (which is a typical sign of a contact form of teaching), was no longer obligatory, but voluntary. Afterwards, in the so-called Covid period, a hybrid form (HYBRFVYUC) of teaching UCNSTP came to the fore. In its fundamental essence, it represents a disjunction of the contact and distance form of teaching provided simultaneously in time.

The application period of HYBRFVYUC in CNSTSPE course was provided form February 2022 to December 2022. The implementation of HYBRFVYUC is schematically shown in Figure 5. It represents a model of teaching, in which some students attend classes in person, while others learn from home. Students were randomly divided into those two groups, and we only use ANOVA test to check statistical equivalence based on the data from the pre-test (average scores from previous university courses students' had already passed and which related to the UCNSTP). In other words, the lecturer taught at the same time both remotely and in person, using digital technologies. To make it technically- as well as spectator-friendly, digital technologies used for video transmission were enriched with a CCD camera for spatial recording (Webcam LIVE CAM SYNC 1080P 1080P HD with Built in Digital Microphone) a stand version is possible, but also a version for ceiling installation). For capturing handwritten text as well as images, teachers were recommended to use a visualizer placed on the demonstration table (Epson ELPDC13). Figure 6 shows the accessories for HYBRFVYUC that we have tested, and we also fully recommended for this form of teaching.

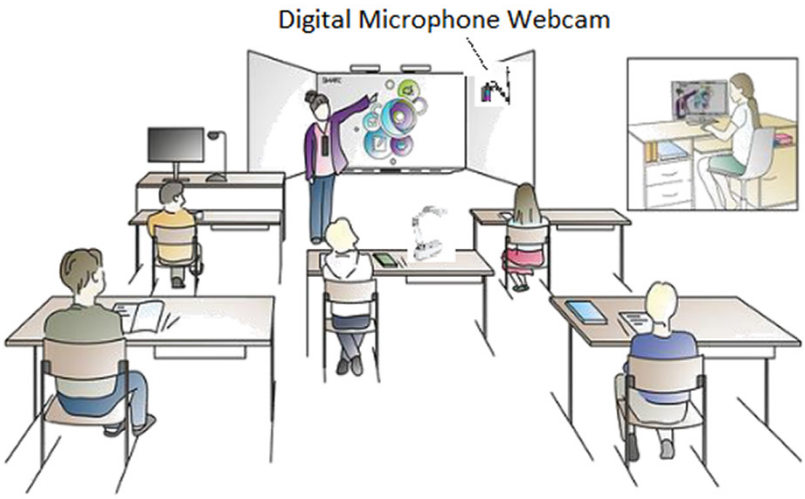

Fig. 5. Design and application of HYBRFVYUC—scheme. (illustrated figure [12])

Fig. 6. Tested and recommended accessories for HYBRFVYUC (illustrated figure [13])

3 Empirical research on the application possibilities of FVNV models of science and technologically oriented curriculum (UCNSTP) during the Covid 19 pandemic in the real conditions of teaching practice in Slovak educational system

Research question (formulated more globally): Do the forms of teaching (applied during the Covid 19 pandemic) influence students' results in science-oriented course of UCNSTP ? By the term students' results we means both, cognitive and affective results.

Narrowed and more specific research question with a deeper focus on (targeting) the cognitive results: Did the students' performances in didactic research tests (average grades in didactic tests) remain the same in all research groups (taught by different forms of teaching)?

3.1 Objectives of the empirical research

1. To find out and statistically analyse the impact of FVCOVIDE (design of which was initiated by the pandemic), on the students' performance in UCNSTP as it comes to their results in cognitive field.
2. To find out and statistically analyse the impact of FVCOVIDE (design of which was initiated by the pandemic), on students' attitudes and opinions on FVCOVIDE UCNSTP and their possible application in the teaching-learning process in the post and neo-covid period.
3. To compare the effectiveness of all newly designed forms of teaching (initiated by the pandemic) of FVCOVIDE with each other and also with the effectiveness of the traditional pre-covid contact form (FVTR)—(KONTFVYUC) UCNSTP.
4. To optimize the theory and practice of FVCOVIDE and to express assumptions about the possibility of introducing it into the permanent practice of teaching university course of natural science and technologically oriented for future teachers.

3.2 Main research hypothesis and method of its verification

HK1 Students attending the course UCNSTP, who were during the pre-covid period taught by traditional way of teaching (KONTFVYUC) will perform higher in cognitive learning (better score in the output didactic test) at the end of the lesson than students taught by the Covid forms of teaching (KOMBFYUC, DISTFVYUC, HY-BRFVYUC).

Design of the verification method of HK1: *output didactic test, Kolmogorov-Smirnov test, Levene's test, Welch's test, IBM SPSS ANOVA plus Post Hoc ANOVA test in Games-Howell's modification.*

3.3 Research design and methodology basis

Theoretical analysis of the research problem showed that it is a problem of assessing the impact of 4 different UCNSTP teaching forms (CONTFSVE, DISTFSVE, KOMBFSVE, HYBRFSVE) on students' results in the research period (before and during the pandemic). The research project was set out to measure students' results in the cognitive area by using input and output didactic test (DT). At the same time, the project defined to measure the results of the attitudes and opinions obtained by the questionnaire in the affective area. Moreover, the project conditions determined to implement such educometrics after the end of active research, that would measure students' level of knowledge. In addition, at the end of the research teaching period, students (who have completed FVCOVIDE) were asked to fill-in an attitude questionnaire.

3.4 Composition of research groups (basic descriptive statistics)

A total number of 1284 students took part in the research. From this number, 355 students were taught in contact teaching form (KONTFVYUC) as a form of pre-study teaching system, 290 students were taught distantly (DISTFVYUC), 277 students used combined form of teaching (KOMBFVYUC), and 362 students were taught in a hybrid form (HYBFVYUC). The students were divided into groups randomly, which initiates the claim that they had the same prerequisites for learning, verified by the initial didactic input test. Therefore, they were considered statistically equivalent in the beginning of the research. At the end of the teaching period, all students were given a didactic output test that reliably measured the level of their cognitive knowledge and also a questionnaire that measured attitudes and opinions about the applied form of the UCNSTP teaching system—that is, the affective area. The basic statistics about the research groups composition is shown in Table 1.

Table 1. The basic descriptive statistics about the research groups composition

Descriptives

DTEST

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
KONTFVYUC	355	18,6873	2,14074	,11362	18,4639	18,9108	13,00	24,00
KOMBFVYUC	277	18,8267	2,09008	,12558	18,5795	19,0739	13,00	24,00
DISCFVYUC	290	17,6034	2,33330	,13702	17,3338	17,8731	10,00	23,00
HYBFVYUC	362	17,3536	2,32459	,12218	17,1133	17,5939	9,00	23,00
Total	1284	18,0966	2,31805	,06469	17,9697	18,2235	9,00	24,00

Statistical normality about the research data: Choosing the suitable statistical test depends on the number of probands in each group. The rule says that if there are more than 50 people in a group, it is appropriate to use the Kolmogorov-Smirnov test, and in a group with less than 50 people, the Shapiro-Wilk test provides more accurate results [9], [10].

In this case, there are more than 100 in each group; therefore, we can:

– automatically use the aforementioned statistical theorem, which globally says that if the number of elements of the selected file is greater than 100 and it was realized by random selection (or was matched), then the distribution of such a file can be considered as normally distributed.
– or use the tests included in IBM SPSS—the Kolmogorov-Smirnov test. We decided to use both of them to increase the validity of the research.

Using the statistical normality test, we test overall number of five null statistical hypotheses (null + alternative), which say that the tested variable is in subgroup 1, 2, 3 and 4 normally distributed (KONTFVYUC, KOMBFVYUC, DISTAFVYUC, HYBRFVYUC). We do not reject the hypothesis if the significance value for the given group is higher than 0.05. In our case, this is true and therefore we do not reject any of the 5 null statistical hypotheses, which means that the condition of normal distribution in each of the research subgroups as well as the research group as a whole is fulfilled (we assess the last column on the right side of the table: sig.= 0.054; 0.074; 0.866).

Output from PC—see Tables 2.1 and 2.2 with the results of the normal distribution test.

Table 2.1. Table with the results of the normal distribution test of the research group as a whole

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
DTEST	,112	1284	<,001	,978	1284	<,001

a. Lilliefors Significance Correction

Table 2.2. Table with the of the normal distribution test of each of the research group

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	FORMAVYUCBY	Statistic	df	Sig.	Statistic	df	Sig.
DTEST	KONTFVYUC	,108	355	<,001	,977	355	<,001
	KOMBFVYUC	,107	277	<,001	,975	277	<,001
	DISCFVYUC	,112	290	<,001	,976	290	<,001
	HYBFVYUC	,126	362	<,001	,974	362	<,001

a. Lilliefors Significance Correction

Research data show that the condition of normal distribution in the research group DTEST, as well as in each of the research sub-groups (KONTFVYUC, KOMBFVYUC, DISCFVYUC, HYBFVYUC) is fulfilled, according to the Kolmogorov—Smirnov test, as well as according to Shapiro-Wilk test (see Tables 2.1 and 2.2 column Sig claim).

In the next step we verified whether the variances of the dependent variable are the same in all three research groups, i.e. whether if the condition of the research groups homogeneity is fulfilled. The Levene's and Welch's statistical test for equality of variances was used for this purpose.

Homogeneity of the research sample: By the homogeneity test of the research sample, we mean (in a broader sense), the test of "approximate" equality of variances (Levene's test), but also the test of "approximate" equality of means (Welch's test).

Table 3.1. The results of Levene's test of equality of variances in groups

Tests of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
DTEST	Based on Mean	2,507	3	1280	,057
	Based on Median	2,116	3	1280	,096
	Based on Median and with adjusted df	2,116	3	1258,876	,096
	Based on trimmed mean	2,530	3	1280	,056

Table 3.2. The results of Welch's test of equality of variances in groups

Robust Tests of Equality of Means

DTEST

	Statistic[a]	df1	df2	Sig.
Welch	36,526	3	694,606	<,001

a. Asymptotically F distributed.

The results of testing the basic research sample (DTEST) as well as all its research groups (KONTFVYUC, KOMBFVYUC, DISCFVYUC, HY-BFVYUC) meet the condition of normality of distribution based on the Kolmogorov-Smirnov test and the

condition of groups homogeneity based on the Welch's test. It follows from this, that it is possible to perform the ANOVA calculation plus the Post Hoc ANOVA test in the Games-Howell modification (see also Figures 7.1 and 7.2).

3.5 ANOVA (Games-Howell modification)

Using an algorithm reflecting the mathematical essence of ANOVA test, we have done a numerical calculation that solved our re-search problem. First of all, we have provided a numerical calculation by ourselves, and afterwards by PC technique in the IBM SPSS statistical programme. In the following paragraphs, we will introduce and comment on both of them.

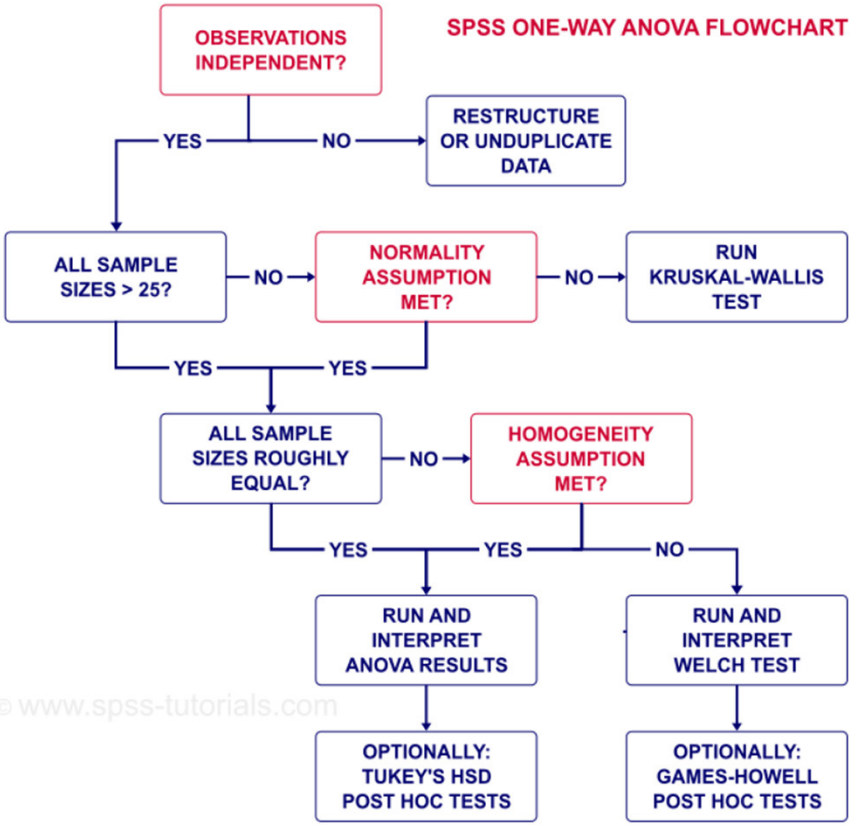

Fig. 7. Using an algorithm IBM SPSS (illustrated figure [14])

The results of the variance analysis (in the form of "intermediate results", we have recorded in an overview Table 2.5. When calculating the variance analysis, we use ANOVA table, which contains a specific p-value. This value indicates that if there were no differences between groups, there is a p-level probability that we would get sample means exactly as we did (for example, a p-value of 0.03 means there is a 3%

probability of getting such results.) In social and behavioural sciences, null hypothesis is usually rejected when p-value equals 0.05 and more.

Table 5. Way of recording intermediate results of ANOVA calculation

ANOVA

DTEST

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	541,913	3	180,638	36,400	<,001
Within Groups	6352,112	1280	4,963		
Total	6894,025	1283			

In Table 5 we can see that the variance between groups is determined from 4 group average scores. It means that there are only 3 degrees of freedom. The variance within groups is 1280. The total variance was calculated from all values and therefore has 1284 minus 1 degrees of freedom, which equals to 1283.

The next step in a one-factor analysis of variance was to determine whether the variance between groups is significantly greater than the variance within groups. We made a decision based on the results of F- test. First, we formulated the null and alternative statistical hypothesis:

Ho: There is no difference between variance between groups and variance within groups.

Ha: The variance between groups is greater than the variance within groups.

We perform testing at the alpha = 0.05 significance level

F criterion was counted according as follows:
F = variance between groups divided by variance within groups
F = 180.638/4.963 = 36.4

We compare the calculated value F = 36.4 with the critical value FKr for the significance level of 0.05 and f1 = 3 and f2 = 1280 degrees of freedom, i.e. with the value of FKr = 2.61. [9], [10]. Since the calculated value is greater than the critical value, we reject the null hypothesis and accept the alternative hypothesis. Thus, the variance between groups is significantly greater than the variance within groups. From this finding, the groups cannot be considered as random selections from the same basic set. In other words, there are statistically significant differences between the results of students in different research sub-groups.

The above-demonstrated calculation is nowadays more often carried out using PC technology and some statistical programme. We have chosen the IBM SPSS statistical software. In the following part, we will present and comment on this computer calculation with an emphasis on the results visualized by the mentioned programme. Tables 7.1 and 7.2 entitled "Result of the statistical test of intergroup effects—ANOVA" contains information containing the most important results of the analysis of variance. Due to the complexity of the table, we will describe only those data we need in the text of the research report. In the column marked "df" there are so-called degrees of

freedom—we are specifically interested in the line with the variable form of teaching (df=3). The column marked "F" contains the result of the calculation of the test criterion—we are specifically interested in the line in which the variable DTEST is, i.e. F = 36.4. In the "sig." column, the significance value (Sig. < 0.001) is calculated. Analysis of variance tests the null statistical hypothesis, which says, that there is no statistically significant difference between the groups as it comes to dependent variable. If the significance value is greater than 0.05, we do not reject the null hypothesis. If the significance value is less than or equal to 0.05, we reject the null hypothesis. To conclude, we have confirmed a statistically significant difference between the 4 groups. Based on this test, however, we cannot yet say which groups specifically have a significant difference—for this purpose, the table of post-hoc tests marked as "Multiple Comparisons" (Tables 9.1 and 9.2) will serve us.

Table 7.1. Result of the ANOVA statistical test of intergroup effects

ANOVA

DTEST

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	541,913	3	180,638	36,400	<,001
Within Groups	6352,112	1280	4,963		
Total	6894,025	1283			

Table 7.2. Summarization of ANOVA test results

DTEST

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	541,913	① 3	180,638	36,400 ③	<,001 ④
Within Groups	6352,112	② 1280	4,963		
Total	6894,025	1283			

F(3,1280)= 36,4; p<0,001.
① ② ③ ④

Standard notation of Analysis of variance statistical test:

$$F(3.1280) = 36.4;\ p < 0{,}001.\ \text{(see Table 7.1)}\ \eta^2 = 0.\ 079\ \text{(see Table 8.1)}$$

We have obtained this notation by filing-in the following template (see Table 7.2)

F("df of variable", "df Error") = "F-value"; p – value = "value of sig"

To make it complete, it is important to explain "Partial Eta Squared" column (Tables 8.1 and 8.2). This available shows the measure of the effect. Its detailed explanation and description is written in the following text.

Measure of the effect. If necessary, it is possible to add the effect rate values in the results notation. In case of variance analysis, the variable is called η^2 (Eta2, or fully written "eta squared"). Concrete values eta squared can be found in

Tables 8.1 and 8.2. The effect rate gives the information about the effect size or significance among detected group differences. In Table 8.1 entitled—Results of Anova Effect Sizes we can see that the eta squared equals 0.079.

Table 8.1. Results of ANOVA effect sizes

ANOVA Effect Sizes[a]

		Point Estimate	95% Confidence Interval Lower	Upper
DTEST	Eta-squared	,079	,051	,106
	Epsilon-squared	,076	,049	,104
	Omega-squared Fixed-effect	,076	,049	,104
	Omega-squared Random-effect	,027	,017	,037

a. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

Table 8.2. Summarization of ANOVA effect sizes

ANOVA Effect Sizes[a]

		Point Estimate	95% Confidence Interval Lower	Upper
DTEST	Eta-squared	,079	,051	,106
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	Omega-squared Fixed-effect	,076	,049	,104
	Omega-squared Random-effect	,027	,017	,037

a. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

According to Cohen [9], [10] we interpret the effect size values (for the coefficient η^2) as follows:

- small effect rate: $\eta^2 > 0.01$
- medium effect rate: $\eta^2 > 0.059$
- large effect rate: $\eta^2 > 0.138$

In this case, the value of $\eta^2 = 0.079$ means a medium effect.

3.6 ANOVA plus post hoc test

Analysis of variance tests the null statistical hypothesis that states there is no statistically significant difference between groups as it comes to dependent variable. If we subsequently reject the hypothesis based on the obtained result (significance value

is less than or equal to 0.05), it would mean that 4 research groups who took part in this research (KONTFSVE, DISTFSVE, KOMBFSVE, HYBRFSVE) "globally" differ their performance achieved in didactic output test (average score). In other words, we have found out that groups differ from each other in their performance, meaning groups are not the same, but still do not know which of the groups differs directly differs from each other and to what extent. For example, it is also possible that each of the groups will have significantly different mean values (mean didactic test score in percent). In order to find it out, it is necessary to provide the post-hoc tests, which identify exactly pairs of groups with significant differences in the dependent variable.

Since there are multiple modifications of post-hoc tests, we have chosen the most suitable for our research. Different authors prefer different post-hoc tests. IBM SPSS recommends LSD, Tukey, and Duncan modifications for this type of the research.

Post-hoc tests of the analysis of variance do not compare only two groups as in the t-test, but compare several groups simultaneously. It means that three statistical comparisons are provided for three pairs of groups. Similarly, six statistical comparisons have to be done for four pairs of groups. The more comparisons are done, the stricter the significance level should be. In this pedagogical research, we have chosen the significance level α of 0.05 value.

In the "Multiple Comparisons" (Tables 9.1 and 9.2), we first explain the first two columns, marked as "I" and "J". The rows contain pairs of all possible combinations of teaching forms (KONTFVYUC, KOMBFVYUC, DISTAFVYUC, HYBRFVYUC). The "Mean Difference (I-J)" column reports the size of variance between the average score of each group pair. The "Sig" column gives the statistical significance value. If the significance is greater than 0.05, we accept the null statistical hypothesis of the average score equality of the groups (i.e. there is no significant difference between the groups). If the significance is lower than or equal to 0.05, we reject the null hypothesis of the average score equality of the groups (i.e., there is a significant difference between the groups). In the table, this fact is visualized by an asterisk (*) at the end of the number entry in its upper part. In this research, we did not find any statistically significant differences between the groups KONTFVYUC—KOMBFVYUC. However, the statistical analysis has revealed statistically significant differences between the other pairs of research groups.

In conclusion, it should be stated that the ANOVA Post Hoc Test was also provided in the LSD and Games-Howell modifications. Both statistical results are mutually supportive, which increases the validity of the obtained research results.

Table 9.1. Results of statistical ANOVA Post hoc testing and their interpretation

Multiple Comparisons

Dependent Variable: DTEST

	(I) FORMAVYUCBY	(J) FORMAVYUCBY	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
LSD	KONTFVYUC	KOMBFVYUC	-,13939	,17859	,435	-,4898	,2110
		DISCFVYUC	1,08388*	,17633	<,001	,7380	1,4298
		HYBFVYUC	1,33373*	,16640	<,001	1,0073	1,6602
	KOMBFVYUC	KONTFVYUC	,13939	,17859	,435	-,2110	,4898
		DISCFVYUC	1,22327*	,18716	<,001	,8561	1,5904
		HYBFVYUC	1,47312*	,17783	<,001	1,1242	1,8220
	DISCFVYUC	KONTFVYUC	-1,08388*	,17633	<,001	-1,4298	-,7380
		KOMBFVYUC	-1,22327*	,18716	<,001	-1,5904	-,8561
		HYBFVYUC	,24986*	,17556	<,001	-,0946	,5943
	HYBFVYUC	KONTFVYUC	-1,33373*	,16640	<,001	-1,6602	-1,0073
		KOMBFVYUC	-1,47312*	,17783	<,001	-1,8220	-1,1242
		DISCFVYUC	-,24986*	,17556	<,001	-,5943	,0946

Table 9.2. Results of statistical ANOVA post hoc testing and illustrative subtraction procedure

Multiple Comparisons

Dependent Variable: DTEST

	(I) FORMAVYUCBY	(J) FORMAVYUCBY	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
LSD	KONTFVYUC	KOMBFVYUC	-,13939	,17859	,435	-,4898	,2110
		DISCFVYUC	1,08388*	,17633	<,001	,7380	1,4298
		HYBFVYUC	1,33373*	,16640	<,001	1,0073	1,6602
	KOMBFVYUC	KONTFVYUC	,13939	,17859	,435	-,2110	,4898
		DISCFVYUC	1,22327*	,18716	<,001	,8561	1,5904
		HYBFVYUC	1,47312*	,17783	<,001	1,1242	1,8220
	DISCFVYUC	KONTFVYUC	-1,08388*	,17633	<,001	-1,4298	-,7380
		KOMBFVYUC	-1,22327*	,18716	<,001	-1,5904	-,8561
		HYBFVYUC	,24986*	,17556	<,001	-,0946	,5943
	HYBFVYUC	KONTFVYUC	-1,33373*	,16640	<,001	-1,6602	-1,0073
		KOMBFVYUC	-1,47312*	,17783	<,001	-1,8220	-1,1242
		DISCFVYUC	-,24986*	,17556	<,001	-,5943	,0946

3.7 Conclusion of post hoc testing

Calculated value of F (3,1280) equals 36.4 while p-value is lower than 0.001. As a matter of fact that F is greater than the critical value of FKR, we reject the null hypothesis and accept the alternative hypothesis. Variance between students' groups (taught by 4 different forms of teaching) is therefore significantly greater than the variance within the groups. It follows from this finding, that the groups cannot be considered as random selections from the same basic set. In other words, there are statistically significant differences between the results of students from 4 research groups (taught by 4 different forms of teaching).

If one-way Anova analysis leads to conclusion that there are statistically significant differences between the average scores of students' groups, it is necessary to identify those scores which show statistically significant differences. In order to assess the differences between all pairs of group average scores at the same level of significance, we have provided the Anova Post Hoc tests of LSD and Dukan version. Results of these tests are presented in Table 11. From all considered pairs of averages, only the results of two groups (KONTFVYUC and KOMBFVYUC) are statistically not significant. All other assessed differences between the pairs of research group average scores are statistically significant. In Table 9.2, statistically significant averages are marked with an asterisk (*).

4 Verification of the main research hypothesis in the field of cognitive learning

First of all, we consider suitable to remind the formulation of main hypothesis HK1: Students attending the course Elementary science with didactics, who were during the pre-covid period taught by traditional way of teaching (KONTFVYUC) will perform higher in cognitive learning (better score in the output didactic test) at the end of the lesson than students taught by the Covid forms of teaching (KOMBFYUC, DISTFVYUC, HY-BRFVYUC)

In this research, hypothesis H1 was verified by Anova statistical method and the subsequent Post Hoc tests. One-way analysis of variance has proved that:

1. Average students' scores achieved in the didactic output test depend on the form of teaching (KONTFVYUC, KOMBFVYUC, DISTAFVYUC, HYBRFVYUC). $F(3.1280)= 36.4$; $p<0.001$. $\eta^2=0.079$.
2. ANOVA post-hoc test (in LSD modification and Games-Howell modification) identified the following significance of differences in average students' scores achieved in didactic output test (based on different forms of teaching—KONTFVYUC, KOMBFVYUC, DISTAFVYUC, HYBRFVYUC):

Difference between the average students' scores achieved in KONTFVYUC teaching and KOMBFVYUC teaching is not statistically significant. In other words, the average scores achieved in didactic output test is statistically equivalent.

Difference between the average students' scores achieved in other pairs of groups is statistically significant (see Tables 9.1 and 9.2). It follows from the statement above, that H1 research hypothesis was not confirmed at the significance level of 0.01. For this reason, we reject the H1 hypothesis and accept the alternative hypothesis HK1 saying:

HK1a. Students attending the course UCNSTP, who were during the pre-covid period taught by traditional way of teaching (KONTFVYUC) will not perform higher in cognitive learning (better score in the output didactic test) at the end of the lesson than students taught by the Covid forms of teaching (KOMBFYUC, DISTFVYUC, HY-BRFVYUC).

5 Statistical interpretation of research hypotheses (based on statistical probability)

Interpretation of research results is based strictly on the statistical hypotheses verification and on statistical probability. In the following part of the paper, which is written in a structured, systematized and a compressed form, we present predominantly a balance analysis of research hypotheses. It finally results into statistical interpretation of research data based on statistical probability.

Interpretation of Hypothesis HK1a: Although students attending the course UCNSTP who were during the pre-covid period taught by traditional way of teaching (KONTFVYUC) did not perform higher in cognitive learning (better score in the output didactic test) than students taught by the Covid forms of teaching (KOMBFYUC, DISTFVYUC, HY-BRFVYUC), according to Post Hoc Statistical Test results, students with contact teaching form in the pre-covid period and students with combined teaching form during covid period achieved statistically equivalent results. Here we would like to emphasize that mentioned statements are not mutually exclusive!!!

On a statistical-interpretive level, this means that: Effectiveness of teaching (in terms of cognitive performance in didactic output test), during the pre-Covid period (as a contact form) and then the combined form in covid period, were statistically equivalent. However, there was a statistically significant difference among the other combinations of teaching forms (they were not statistically equivalent). The above is clearly shown in Table 10.

Table 10. Differences among group average scores

	KOMBFYUC	KONTFVYUC	DISTFVYUC	HYBFVYUC
KOMBFYUC	.....			
KONTFVYUC	Statistical "equivalence" in performance in DT	.....		
DISTFVYUC	*Statistically significant difference in performance in DT	*Statistically significant difference in performance in DT	.....	
HYBFVYUC	*Statistically significant difference in performance in DT	*Statistically significant difference in performance in DT	*Statistically significant difference in performance in DT	.....

Finally, we have arranged group average scores ascendently, according to their results achieved in didactic output test. We have done so in both, absolute as well as relative metrics. The results are as follows: 1. KOMBFVYUC 18.8267 points (75.3067%) 2. KONTFVYUC 18.6873 points (74.7492%) 3. DISTFVYUC 17.6034 points (70.4136%) 4. HYBFVYUC 17.3536 points (69.4144%).

Note: *We would like to point out the terminological difference between the phrases equivalent and statistically equivalent. Our research did not prove equivalent performances, but statistically equivalent performances of students taught by contact form of teaching in pre-Covid period and by combined form of teaching during the Covid period.*

Our research—Teaching of Natural Science and Technologically Oriented University Course for Future Teachers in the Period of Covid 19 was also carried out with a questionnaire survey that investigated the affective component of the mentioned teaching. For reasons of scope, it is not possible to present more detailed conclusions from this research here. They will be published in detail in [11], Some aspects of the conclusions of the mentioned research, but only in a globalized and applied form will be mentioned in the next part called—Globalization of research results and their possible application into real teaching practice.

6 Globalization of research results and their possible application into real teaching practice

This research was implemented into the university educational process of natural science- and technologically-oriented character for future teachers. Therefore, research results are significant mainly for natural science- and technologically- oriented curriculum of university courses. It follows from the above, that results cannot be generalized for teaching different sciences, such as humanities, social sciences or art-sciences. Moreover, they cannot be generalized for all levels of education. The results of this research can become an impulse to start thinking about the way of teaching in case of other crises like viral infections, climate disasters, geopolitical conflicts, etc.. Based on research results we claim that it is possible replace a traditional contact pre-covid form of teaching by a combined form of teaching similar to the one we designed in the covid period. For examples, lectures would be transferred to distance mode, while laboratory exercises and seminars would stay in a contact mode. Furthermore, we suggest to thing about the possibility of teaching in a combined (hybrid) form even in non-crisis periods. In our opinion, a traditional contact form of teaching could be replaced with a combined form at least in external study programmes. Economically and pragmatically, it would be the most efficient and acceptable to do so on the basis of so-called "teaching blocks". However, we emphasize again that these recommendations are based on our research only for UCNSTP natural science- and technologically- oriented subjects.

Recommendations (based on this research) for teachers of UCNSTP university course as it comes to the forms of teaching (in the following areas):

Pedagogy – especially effectiveness of teaching on the platform of didactic output tests

Economy – primarily the financial and personnel issues of schools

Personal comfort – mainly that of students, but also teacher's (comfort while studying, saving time, saving money and learning from the comfort of their own home, etc…)

Table 11. Differences among group average scores (Pedagogy, Economy, Personal comfort)

	Pedagogy	Economy	Personal comfort
KOMBVYUC	++	++	+
DISTFVYUC	+	+	++
HYBRFVYUC	+	+	++
KONTFVYUC	++	+	+

Note: KONTFVYUC = Contact form of education, DISTFVYUC = Distance education, KOMBFVYUC = Combined form of education, HYBRFVYUC = Hybrid form of education.

In our opinion, combined form of UCNSTP with didactics for future teachers, is the most promising form mainly for university students and education of adults in general. Currently, it optimally takes into account not only didactic, but also economic and individual personality specificities. Its applied research needs to be further developed, both on the pedagogical and technical levels.

Distance form of teaching (distance education) of UCNSTP with didactics for future teachers, seems to be the most suitable form especially for extraordinary crisis situation, when educational institutions have to be completely closed for various reasons, such as virus pandemics, military, economic and climate crises.

Contact form of teaching UCNSTP is traditional form that is very important in every period of human lives. However, we see some limitation to its application in future, because to some extent it limits personal as well as economical specificities.

Hybrid form of teaching UCNSTP, represents a border between the contact- and combined- form of teaching. It is suitable for temporary individual impossibility to participate in contact and combined form of teaching due to e.g. health problems, hospitalization, or maternity leave. Its applied research needs to be further developed, both on the pedagogical and technical levels. Hopefully, it will become a number one topic in pedagogical researches soon.

7 Conclusion

Based on the provided empirical research, we have come to conclusion that government decision to close schools during Covid 19 pan-demic, will affect the development and organization of the entire educational system not only in Slovakia, but also on a global scale. There-fore, we are convinced that it is necessary to further reflect on the strengths and weaknesses of teaching forms and methods applied in special conditions. Moreover, it is very important to reflect on them in order to be prepared for further possible restrictions. Finally, the acquired experience from teaching during pandemic could be used to build better and more effective educational systems in future.

The issue of innovations in teaching natural science and technical and technological subjects with proper methodology part can be found in several foreign journals,

such as [5], [6], [7], This means, the paper examines specific didactic phenomena of natural- and technological- character, with an emphasis on elementary physics, biology, ecology, and technologies.

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