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Research Article

Particular quantitative analysis of accesses to mathematical study sources

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Due to the occurred pandemic situation in the world, the importance of the distance forms of the learning has been increased. In the environment of the university education, the full-time studies became similar as the part-time studies according to the fulfilling the requirements on students. The wide spectrum of the online techniques and strategies has been proposed yet. In this paper, the elementary level of the distance materials is considered regarding the essential environment of the learning system Moodle. The activity of the participants of the Moodle courses is available in the system itself. However, the further detailed statistical analysis is not directly integrated and this type of the analysis can be also an advantageous feedback for the other academics. Advantages can be in the form of an identification of knowledge about the behaviour of students in courses in general. Moreover, the consideration of the statistical significance is appropriate for conclusions of an identified students' behaviour in a quantitative sense, as can be seen in this article with the particular analysis of the students distance access to mathematical study sources.

Keywords: Quantitative analysis, testing hypotheses, time analysis, cluster analysis, discrete autocorrelation functions, mathematics; study sources

1. Introduction

Due to the appeared problems in the educational field in the frame of the pandemic situation in the world, a wide spectrum of the strategies based on ICT techniques (Roth & Price, 2016) have been proposed or utilized. The quantitative research (Stockemer, 2019) can have the significant importance in descriptions of this occurred phenomenon, when the full-time studies became similar as the part-time studies with regards to the distance approaches. On the significance level (Gauthier & Hawley, 2015), the conclusions of this type of analyses can be advantageous and also inspired for other academics in a preventive sense. Moreover, the quantitative analysis should contain the time-based analysis (e.g. Chramcov & Balate, 2008; Kozel, 2018). Occurred aspects of the distance learning can be then analyzed for their feedback evaluations. As can be seen in this article, the cluster analysis (Bijnen, 1973) and the analysis of estimated discrete autocorrelation functions (Hunt, 2016) could be suitable statistical tool for time-based measurements with a guarantee of the statistical significance (Barot et al., 2020).

The application area of this article is based on the mathematical study sources located on the e-learning system Moodle. The system Moodle can be considered as one of the significant implementations of ICT approaches (Roth & Price, 2016). For considered courses, interactive animations were proposed and implemented using by the technology of H5P (e.g. Homanova & Havlaskova, 2019), which is bound with the HTML5, CSS3 and JavaScript technology. Many researches have been frequently focused on the platform Moodle with the analyses in a context of educational approaches, e.g. (Polasek, 2019). The opposite types of ICT utilizations can be seen

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e.g. in using the social networks in classes (Simik, 2017). The interactive animations with teacher comments are described in (Krpec & Barot, 2020) focused on educational strategies attended due to the pandemic situation. The topic with considering the interactive tools has been frequently researched (e.g. Bartek et al., 2018). Therefore, this type of tools can be classified as the actual implementation of ICT in the field of education.

In general, study materials have a significant role in the field of the university education (Sikorova et al., 2019a). The programmable background of all the proposed materials can be appropriately corresponding on the pedagogical cybernetic principles with a feedback control loop (Gushchin & Divakova, 2015). These principles are similar as in the technical cybernetics (e.g. Navratil et al., 2020) and built on the similar theoretical key backgrounds. In the frame of this strategy, the inclusion of the educational tools or materials can be suitably based on a wide spectrum of software platforms, e.g. as the denoted H5P or GeoGebra (e.g. Korenova et al., 2020). The utilization of the GeoGebra is frequently seen in the field of the STEM education (Hott & Dibbs, 2020).

In the proposed and presented quantitative analysis, the essential approaches of the descriptive statistics and testing the essential types of hypotheses are applied. However, the analysis of similarities and a time-based analysis should be significantly important for an evaluation of the previous educational period with constraints caused by the pandemic situation in the world. The visiting statistics from the e-learning system Moodle are more detailed processing with regards to the study fields and to a character of the visited mathematical courses at the Department of Mathematics with Didactics at University of Ostrava in the first year of the new bachelor study programme since academic year of 2019/2020. All research questions are proposed with regards to the consideration of the statistical significance. In the presented statistical analysis, 22 students of the mathematics for future teachers of the second grade of elementary schools are considered with 10466 records of the approaching the study online courses at the department.

1.1 Quantitative Research Methods

The descriptive approaches (Gauthier & Hawley, 2015) in the frame of a utilization of the empirical statistical characteristics can be illustrative for the considered sample of a population (averages, standard deviations, minimums, maximums, medians) with their displaying (e.g. in histograms or boxplots). Moreover, similarities across groups of data according to numbered parameters can be provided using the Cluster analysis (Bijnen, 1973) with computation with the Euclidean distances between vectors of parametrical values (with possible displaying in dendrograms). However, these statistics can be used only for the illustration of the situations occurred by a selected sample of a population.

Therefore, an induction and a conclusion can be possible to be summarized only with regards to the consideration the statistical significance by methods of the testing the hypotheses (Gauthier & Hawley, 2015). The significance level (Gauthier & Hawley, 2015) has been frequently set on the level a = 5%, respectively 0.05 in the educational research yet, e.g. in (Dobesova et al., 2015; Simbartl & Honzikova, 2016). The statistical methods determined for purposes of the testing the hypotheses can be classified according to the aim of their applications (Gauthier & Hawley, 2015): a confirmation of an existence of a non-zero correlation, paired values comparisons (Paired T-test or Wilcoxon Paired test), medians or mean values comparisons (T+F test or Mann-Whitney test; ANOVA or Kruskal-Wallis test), variances comparisons (F test or Kolmogorov-Smirnov test), testing a homogeneity of a distribution of frequencies in contingency tables (Chi-Squared test).
Each of these tests of hypotheses assumed, that there is a pair of a zero and an alternative hypothesis (#H_0 and #H_1) defined for the particular research question (RQ#). The statistical software can obtain results of the testing the hypothesis in a form of the p value (0 .. 1) (Gauthier & Hawley, 2015). According to the comparison of this achieved p value with the significance level a, two possible situations can be occurred (Gauthier & Hawley, 2015): $p < a$: the zero hypothesis is rejected in favor of the alternative hypothesis on the significance level a; ($p > a$) or ($p = a$): the zero hypothesis is failed to rejected on the significance level a.

A final selection of methods for the described situation in this section depends on the normality of data. The normality of data can be considered with some guarantee on the sample size interval, as can be e.g. seen on the particular research on a behaviour of a normality in the educational research with 2067 respondents (Vaclavik et al., 2019). For purposes of the resulting the normality of data, the Shapiro-Wilk test (applied e.g. in Vaclavik et al., 2019) can be used in favor of the appropriate selection of the method for the testing the hypothesis.

If data does not fulfil the normality (Vaclavik et al., 2019) (p value of own Shapiro-Wilk test is lower than α), then the non-parametrical tests are used. These tests can be also used for the smaller volume of the respondents, i.e. exact occurred situations. Into the category of non-parametrical tests belong (Gauthier & Hawley, 2015): Mann-Whitney test of medians (with 2 grouped variables) (characterized by criterion U), Kruskal-Wallis (with 3 or more grouped variables) (characterized by criterion H and H_c) and Wilcoxon paired test (characterized by criterion W). In the opposite case, if the normality is achieved, the parametrical tests are used (T+F test, ANOVA, Paired T test). Although, on the Chi-Squared test (characterized by criterion χ^2 and degrees of freedom DF), the classification according to the normality has not any influence. For purposes of this article, the exact version of tests will be used for reason of the smaller volume of the respondents; therefore, the non-parametrical tests will be applied on the research data.

In case of the rejecting the zero hypothesis, an effect size (Tomczak & Tomczak, 2014) is used to be denoted in addition for determination of the effect of this rejecting. For the non-parametrical respectively for the exact tests, there are the following effect sizes (Tomczak & Tomczak, 2014):

- Mann-Whitney test: effect size r (small: .10 – .30, medium: .30 – .50, large: higher than .50)
- Kruskal-Wallis: effect size η^2 (small: .01 – .06, medium: .06 – .14, large: higher than .14)
- Wilcoxon Paired test: effect size r (small: .10 – .30, medium: .30 – .50, large: higher than .50)

In addition, the correlation coefficient R (Gauthier & Hawley, 2015) (widely used e.g. in Cieslar et al., 2020). The correlation coefficient can be divided into following categories (Gauthier & Hawley, 2015): R: 0 – .19 significant week, .20 – .39 week, .40 – .59 medium, .60 – .79 strong, .80 – 1 significant strong correlation. For purposes of the analysis of the tightness of bindings within discrete time signals (Hunt, 2016), the estimated discrete autocorrelation function (Hunt, 2016) with m equal to one tenth of the sample size K (number of the time function values) can be computed as the discrete sequence (1) for given k from the interval $k = 0, \ldots, m$. Value x has the k–th order in the time-based signal.

$$R_{xx}(k) = 1/K \sum_{i=1}^{K-k} x(k)x(k+i) \quad (1)$$

In this paper, the paired comparison of estimated discrete autocorrelation functions is realized in the sense, which was published e.g. in case of the technical signals processing in (Barot et al., 2020). The comparison of the considered pair of the two estimations of the discrete autocorrelation function can be compared with the guarantee of the statistical significance, in addition.

2. Method

The quantitative analysis of the students' distance access to mathematical study sources can have the significant role due to the current pandemic situation in the world as the inspiration for the colleagues in the field of the mathematical education. Therefore, the research questions RQ1 – RQ5 were structuralized with this aim to identified the login access trends in their behaviour in the frame of the study field of the preparing the future mathematical teachers. With regards to the consideration of the statistical significance, the appropriate quantitative methods for the testing the hypothesis complemented by the descriptive methods (e.g. Cluster analysis) are utilized for the conclusions of an analysed students' behaviour in a quantitative sense.

2.1. Proposal of Research Questions for Quantitative Research

In the following realization of the quantitative research, 5 hypotheses $1H - 5H$ are being tested in a connection with the declared research questions RQ1 – RQ5. The research questions are considered for the appearance of the 3 mathematical courses, which has been provided in the online form of the Moodle e-learning system.

- RQ1: At all considered courses, is there identified the linear ratio of dependences between all the total sums of the logins across all courses to each other? Is the lower, resp. the higher frequency, of approaches consistent across behaviour of students?
- RQ2: At all considered courses, are there fulfilled statistically significant paired differences between measured sums of students' logins to the considered pairs of courses?
- RQ3: At all considered courses, are there fulfilled the statistically significant dependences of the total sums of logins on the concrete character of the considered mathematical course?

- RQ4: At all considered courses, are there identified statistically significant dependences of the unified study fields on the total sums of the logins of the students across the courses?
- RQ5: At all considered courses, are there identified statistically significant paired similarities between summed values of the discrete autocorrelation functions to the considered pairs of courses?

2.2. Participants and Data Collection

The method of the obtainment of the data was the analysis of the approaches of the students into the e-learning system. The visiting statistics from the e-learning system Moodle were considered as the more detailed processing of data with regards to the study fields and to a character of the visited mathematical courses at the Department of Mathematics with Didactics at University of Ostrava in the first year of the new bachelor study programme since academic year of 2019/2020.The descriptive computations and the quantitative analysis were based on these students' attendances into the considered mathematical courses.

The students at the Faculty of Education at University of Ostrava have been visited 3 courses in their 1st year of the bachelor study programme: 1st Course – Application of Software in Mathematics (using the wxMaxima, GNU Octave, GeoGebra, PAST Statistics, etc.), 2nd Course – Essentials in Mathematics (propositions, mathematical logic, algebraic structures, etc.) and 3rd Course – Synthetical Geometry (the plane-metrical principles in 2D).

3. Results of Quantitative Research

According to the proposed design of the quantitative research, the computations were realized using by the statistical solution of the PAST Statistics – version 4 (Hammer et al., 2001) or in Microsoft Excel including the programming environment of the Microsoft Visual Basic for Application. The statistical computations were provided according to the describe methods of the quantitative research (cg. Section 1.1). The statistical significance was guaranteed by the principle of the utilized quantitative methods.

The achieved attendance 10466 into the mathematical courses was analysed for the 22 students, i.e. $N = 22$. In each course, the empirical statistical characteristics were obtained, as can be seen in Table 1. In addition, a normality or a non-normality was identified for data of sums of students' attendances using by the Shapiro-Wilk method. The significance level for the testing a normality of data was considered as $\alpha = .05$, usually used in the educational sciences. If p value of the Shapiro-Wilk test is higher than .05, then the parametrical tests of hypotheses should be used. In the opposite case, the non-parametrical variant of tests will be applied.

Regarding the results of the empirical statistics in Table 1, the box plot (Fig. 1) was displayed for the measured students' attendance for the considered mathematical courses.

Table 1.
Sums of Students' Logins into Each Mathematical Course According to Study Fields (N = 22)

	1st Course	2nd Course	3rd Course
Min	7	27	116
Max	242	268	538
Sum	2104	2144	6439
Mean	95.64	97.45	292.68
Stand. dev	58.53	58.88	115.94
Median	96.50	84.50	284.00
Shapiro-Wilk (Normality)	$p = .62 > .05$ Confirmed	$p = .03 < .05$ Confirmed	$p = .38 > .05$ Rejected

Own Source

In Table 2, the study fields are denoted using by the pair of abbreviations. In the first of the study field combination, the final bachelor thesis is provided by student. The following codes for the study fields are unified: Ma – Mathematics, Mu – Music, Ci – Civic Education, In – Informatics, Vi – Visual Arts, Sp – Sports, Te – Technical Education, En – English Language and Cz – Czech Language.

Table 2.
Sums of Students' Logins into Each Mathematical Course According to Study Fields (N = 22)

	1st Course	2nd Course	3rd Course
Mu-Ma	97	46	163
Mu-Ma	153	150	404
Ma-Ci	33	85	324
In-Ma	96	83	336
Ma-Vi	242	146	538
Ma-In	81	86	263
Sp-Ma	155	65	360
Ma-Mu	31	33	244
Ma-Sp	124	120	256
Sp-Ma	124	68	247
Ma-In	102	195	305
Sp-Ma	102	121	408
Te-Ma	46	81	116
Sp-Ma	157	92	261
Te-Ma	7	27	138
Te-Ma	8	33	180
Ma-En	177	268	533
Ma-Te	116	156	367
Ma-In	61	53	315
Ma-Cz	85	84	230
In-Ma	50	114	325

Own Source

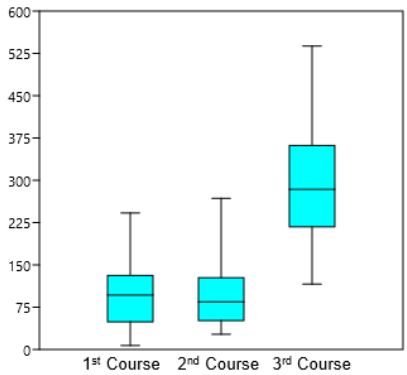

Figure 1. Boxplot of Summed Measured Students' Attendance in Math Courses, *Own Source*

Using the Cluster analysis (Fig. 2) with the selected Ward methods, the similarities in the students' behaviour were analysed with regards to the measured total sums of their logins into all of the 3 mathematical courses. The Euclidean distances of sums logins were considered according to the study fields combinations.

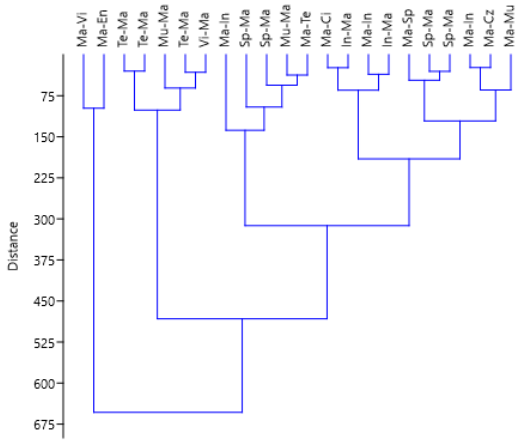

Figure 2. Cluster Analysis According to Sums of Measured Students' Attendance, *Own Source*

As can be seen in Fig. 2, the major similarities were identified at following study fields combinations with the similar behavior of students: Te-Ma, In-Ma or Ma-In.

3.1 Testing Hypotheses Based on Sums of Attendances

3.1.1. Confirmation of Research Question RQ1

For each pair of courses (from set of courses: 1st Course – 3rd Course), the measured total sums of logins were analysed using by the testing the hypothesis $1H$ and by the correlation and regression analysis, in addition.

Zero hypothesis $1H_0$: There is missing any statistically significant linear dependence between the sums of the particular courses, i.e. in the sense that the correlation coefficient is equal to $R = 0$.

Alternative hypothesis $1H_1$: There is some statistically significant linear dependence between the sums of the particular courses, i.e. in the sense that the correlation coefficient is equal to $R \neq 0$.

All resulted p values for $1H$ for each pair of courses were obtained as lower than the significance level $a = .05$. Therefore, there cannot be said that between courses' sums of logins do not exist any correlation relation. Statistical significance was achieved as: $p_{12} = 2.34\times10^{-3} < .05$ ($1H_0$ rejected in favor of $1H_1$, for 1st and 2nd course), $p_{13} = 1.59\times10^{-4} < .05$ ($1H_0$ rejected in favor of $1H_1$, for 1st and 3rd course) and $p_{23} = 8.40\times10^{-5} < .05$ ($1H_0$ rejected in favor of $1H_1$, for 2nd and 3rd course).

The correlation coefficients were determined as: $R_{12} = .61$ (strong correlation by 1st and 2nd course), $R_{13} = .72$ (strong correlation by 1st and 3rd course) and $R_{23} = .74$ (strong correlation by 2nd and 3rd course). The resulted linear dependences between all cardinal variables is displayed in Fig. 3-5 including the regression equations $y = f(x)$.

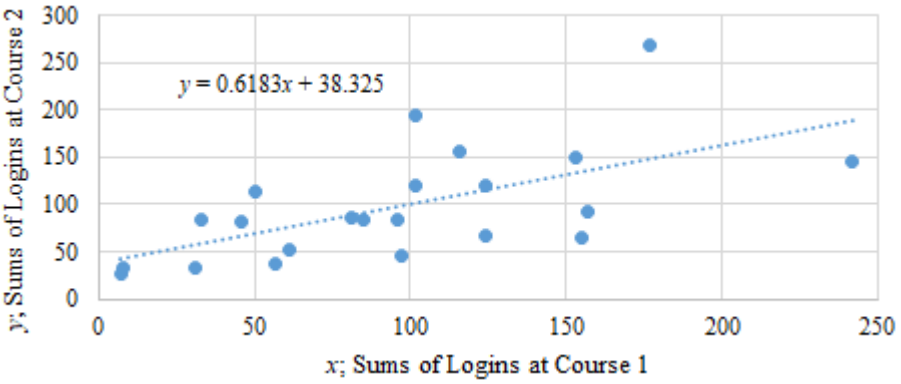

Figure 3. Regression Analysis According to Sums of Measured Students' Attendance in Frame of Pair of 1st and 2nd Course, *Own Source*

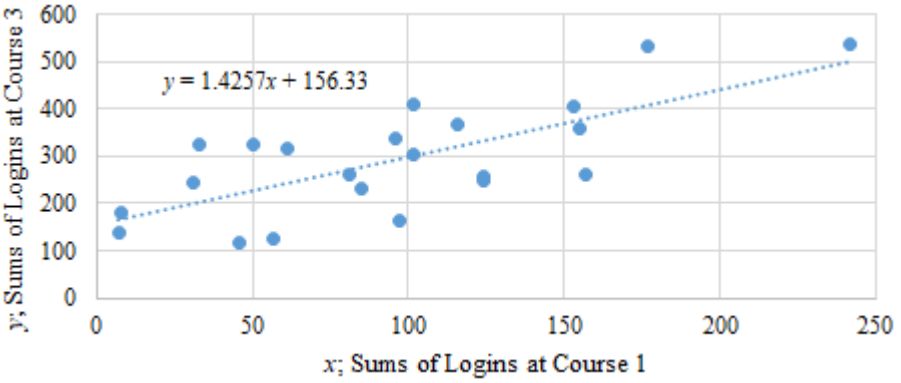

Figure 4. Regression Analysis According to Sums of Measured Students' Attendance in Frame of Pair of 1st and 3rd Course, *Own Source*

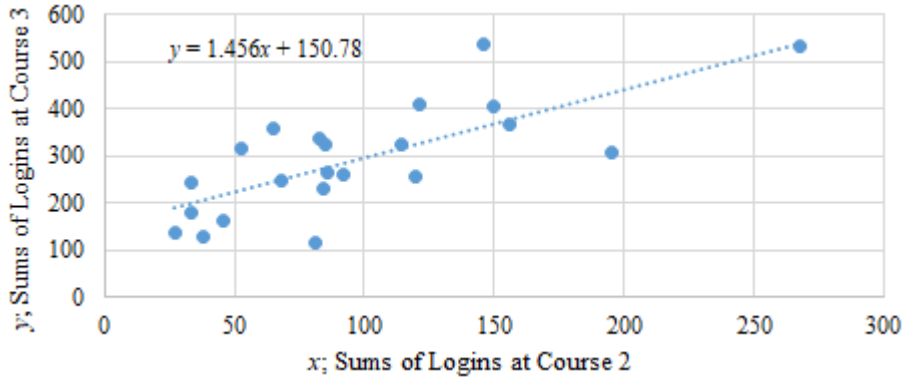

Figure 5. Regression Analysis According to Sums of Measured Students' Attendance in Frame of Pair of 2nd and 3rd Course, *Own Source*

3.1.2. Confirmation of Research Question RQ2

In the hypothesis $2H$, the paired comparisons were being tested for particularly bounded records for each partial respondent using by the Wilcoxon paired test (selection for the reasons of the smaller volume of the respondents as the case of the exact test).

For each respondent, the considered pairs of records of sums of their logins were measured for combinations of courses, i.e. for each pair of courses (1st and 2nd course, 1st and 3rd course and 2nd and 3rd course). The hypothesis $2H$ was defined as:

Zero hypothesis $2H_0$: There are not the statistical paired differences between measured sums of students' logins to the considered pairs of courses.

Alternative hypothesis $2H_1$: There are the statistical paired differences between measured sums of students' logins to the considered pairs of courses.

All resulted p values for $2H$ for each pair of courses were achieved in the following results of p values (with complementing information about the effect size in case of rejecting the zero hypothesis): $p_{12} = .80 > .05$ (testing criterion $W = 134.50$, $2H_0$ fail to rejected for 1st and 2nd courses), $p_{13} = 4.01 \times 10^{-5} < .05$ (testing criterion $W = 253$, $2H_0$ rejected in favor of $2H_1$ for 1st and 3rd courses with large effect size $r = 1$) and $p_{23} = 3.99 \times 10^{-5} < .05$ (testing criterion $W = 253$, $2H_0$ rejected in favor of $2H_1$ for 2nd and 3rd courses with large effect size $r = 1$).

3.1.3. Confirmation of Research Question RQ3

According to the properties of the normality of data (Table 1), for the summarized form of the comparison of medians across all 3 courses (1st - 3rd course), the testing the hypothesis $3H$ was provided using by the Kruskal-Wallis test (the population expresses the non-normality, as can be seen in Table 1). In case of rejecting the zero hypothesis $3H_0$, the effect size is determined. The hypothesis $3H$ was defined as:

Zero hypothesis $3H_0$: There are not the statistically significant dependences of the measured sums of students' logins on the character of the particular course (1st – 3rd course).

Alternative hypothesis $3H_1$: There are the statistically significant dependences of the measured sums of students' logins on the character of the particular course (1st – 3rd course).

The occurred p value for $3H$ was achieved (with complementing information about the effect size in case of rejecting the zero hypothesis) as: $p = 2.39 \times 10^{-8} < .05$ (testing criterion $H = H_c = 35.10$, $3H_0$ rejected in favor of $3H_1$ with large effect size $\eta^2 = 1.74$).

3.1.4. Confirmation of Research Question RQ4

The previously structured Table 2 was unified into the contingency Table 3. For the same appearance within the records of the same study fields, the contingency table was rewritten; moreover, the ordering the first and the second study field in the student's study field combination were also unified.

Table 3.
Contingency Table of Unified Sums of Students' Logins into Each Mathematical Course According to Study Fields

	1st Course	2nd Course	3rd Course
Ma-Mu or Mu-Ma	281	229	811
Ma-Sp or Sp-Ma	662	466	1532
Ma-Ci	33	85	324
Ma-In or In-Ma	390	531	1544
Ma-Te or Te-Ma	177	297	801
Ma-En	177	268	533
Ma-Cz	85	84	230
Ma-Vi or Vi-Ma	299	184	664

Own Source

The structure of the hypothesis $4H$ was considered as:

Zero hypothesis $4H_0$: There are not the statistically significant dependences of the measured sums of students' logins on the unified study fields of all students across the courses.

Alternative hypothesis $4H_1$: There are not the statistically significant dependences of the measured sums of students' logins on the unified study fields of all students across the courses.

The occurred p value for $4H$ was achieved (with complementing information about the effect size in case of rejecting the zero hypothesis) as: $p = 1.08 \times 10^{-39} < .05$ (testing criterion $\chi^2 = 222.96$, $DF = 14$, $4H_0$ rejected in favor of $4H_1$).

3.2 Time-Based Analysis of Attendance of Students

In detail, the analysis is further based on the time-series approaches. The tightness of the discrete signals' bindings is identified. The time bound records (from 14th March to 12th August, i.e. end of semester was moved to 31st August) were exported from the system Moodle in the discrete sequence of value of the login frequency.

For the exported time-series of data (Fig. 6), the discrete estimations $R_{xx}(k)$ (for $k = 1, \ldots, 150/10$) of the autocorrelation functions were computed using the following formula (Code 1) written in the Microsoft Visual Basic for Application for each summarized logins in the time-period.

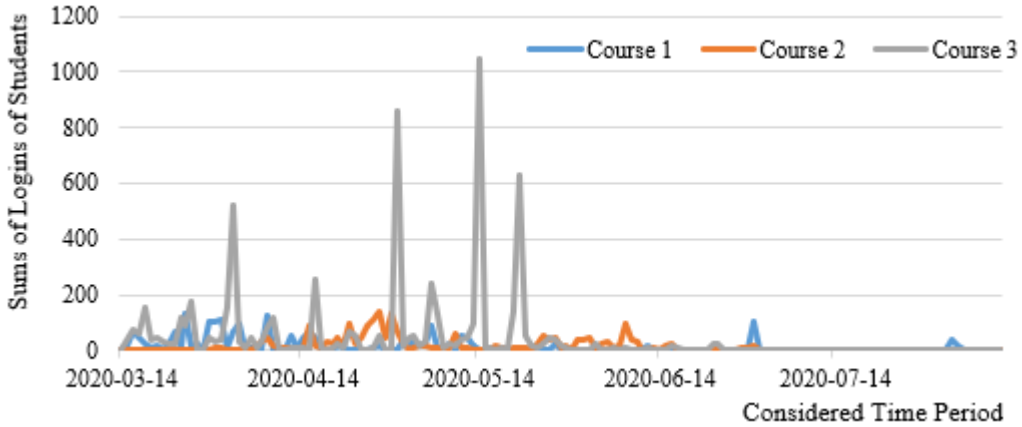

Figure 6. Time Based Discrete Sequence of Sums of Logins for 1st – 3rd Course, *Own Source*

Code 1. Computation of Discrete Autocorrelation Function in Microsoft Visual Basic for Application, *Own Source*

```
Function Rxx(k As Integer, signalValues As Range) As Variant
    Dim Sum As Double
    Dim i As Integer
    Sum = 0
    For i = 1 To (signalValues.Count - k)
        Sum = Sum + signalValues(1, i) * signalValues(1, i + k)
    Next i
    Rxx = 1 / signalValues.Count * Sum
End Function
```

For all computed autocorrelation functions $R_{xx}(k)$, the identification of the similarities was provided for each course (1st – 3rd course) from the time-serialized data, as can be seen in Fig. 7-9. The achieved plots were obtained using by the Cluster analysis with the Ward method. The Euclidean distances were computed from the particular values of each $R_{xx}(k)$.

For the 1st course, as can be seen in Fig. 7, the major similarities were identified at following study fields combinations with the similar behavior of students: Ma-Sp or Sp-Ma and Te-Ma or Ma-Te.

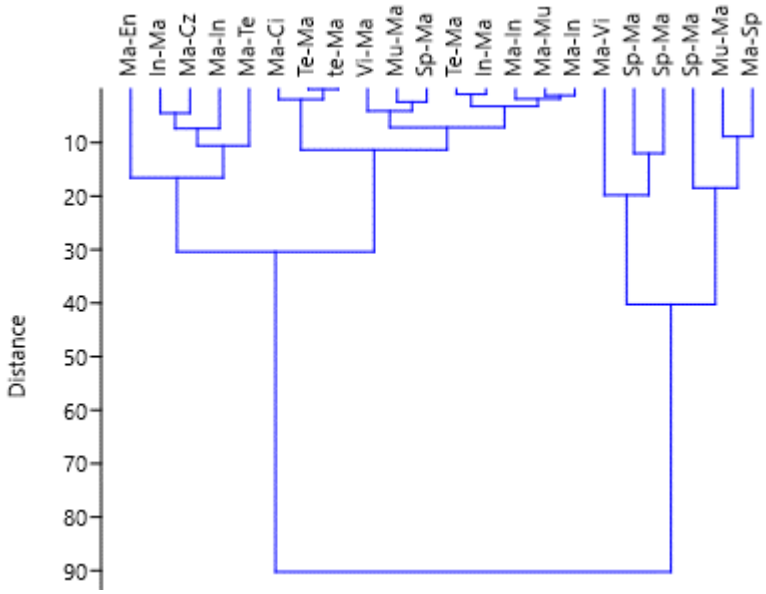

Figure 7. Cluster Analysis for 1st Course According to Students' Time-Serialized $R_{xx}(k)$, *Own Source*

For the 2nd course, as can be seen in Fig. 8, the major similarities were not so clearly identified.

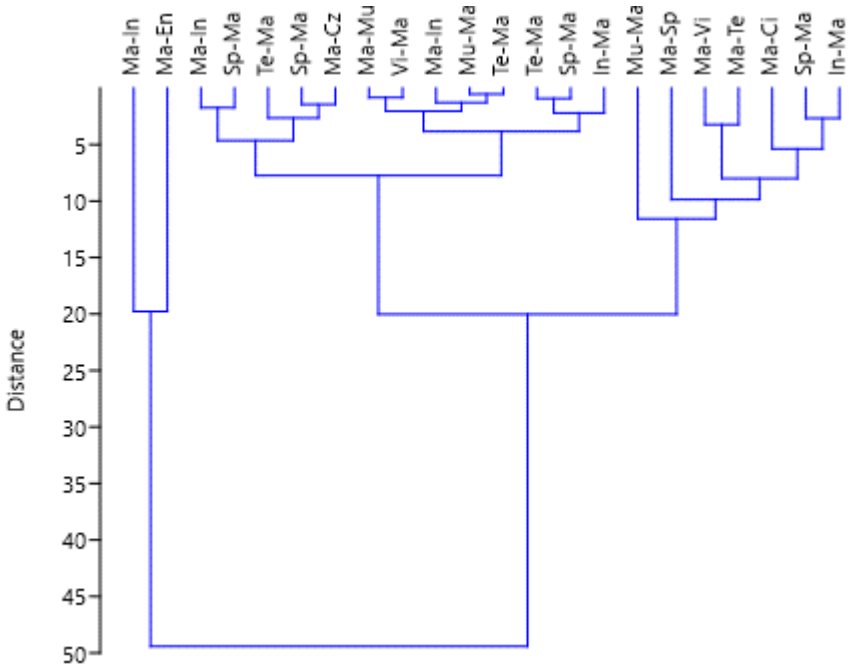

Figure 8. Cluster Analysis for 2nd Course According to Students' Time-Serialized $R_{xx}(k)$, *Own Source*

For the 3rd course, as can be seen in Fig. X, the major similarities were identified at following study fields combinations with the similar behaviour of students: Te-Ma and Ma-In.

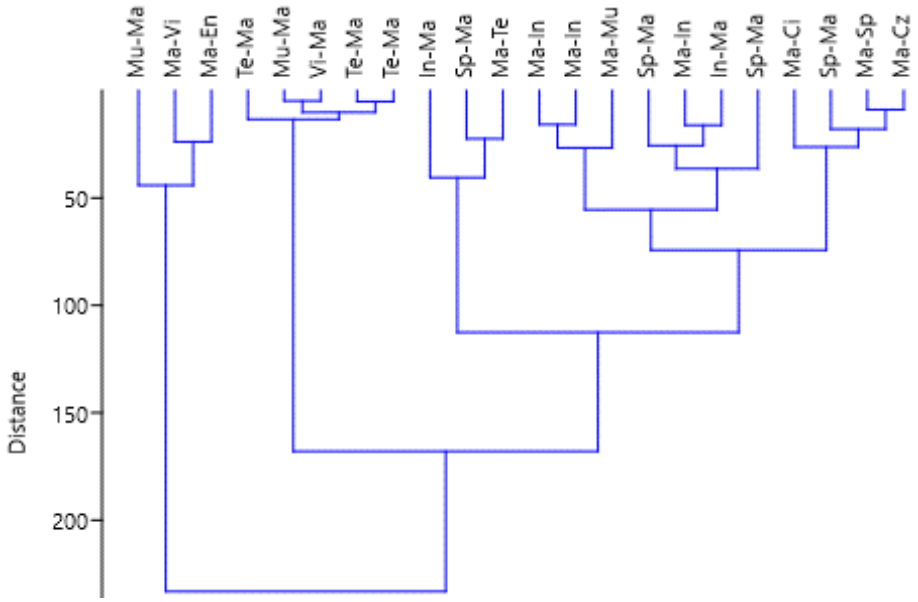

Figure 9. Cluster Analysis for 3rd Course According to Students' Time-Serialized $R_{xx}(k)$, *Own Source*

3.2.1 Confirmation of Research Question RQ5

For each course, the discrete autocorrelation function $R'_{xx}(k)$ were determined as the sums of each k -th value, as can be seen in Table 4 and in Fig. 10.

Table 4.
Discrete Autocorrelation Function for Summed Time-Serialized Data of Logins to 1st – 3rd Course

k	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$R'_{xx}(k)$ Course 1	395.0	50.3	17.0	32.0	15.9	13.1	35.7	21.4	20.6	9.7	9.5	3.7	18.5	17.6	21.0	12.1
$R'_{xx}(k)$ Course 2	183.2	46.0	40.0	32.7	30.1	26.3	18.8	26.8	20.4	19.2	23.6	19.8	18.7	17.4	23.0	22.7
$R'_{xx}(k)$ Course 3	1535.7	158.2	67.4	87.7	68.1	80.1	204.3	401.3	223.0	75.8	68.6	83.0	70.5	96.1	505.5	114.4

Own Source

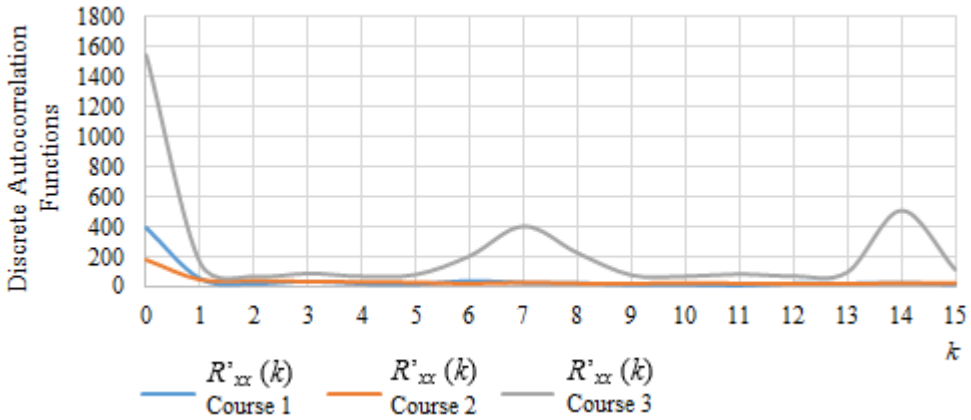

Figure 10. Summed Discrete Autocorrelation Functions for 1st – 3rd Course, *Own Source*

Therefore. the testing hypothesis 5H could be defined with the paired comparisons of the particular values of the autocorrelation functions.

Zero hypothesis 5H_0: There are not the statistical paired differences between values of summed discrete autocorrelation functions of time-serialized students' logins to the considered pairs of courses.

Alternative hypothesis 5H_1: There are the statistical paired differences between values of summed discrete autocorrelation functions of time-serialized students' logins to the considered pairs of courses.

All resulted p values for $5H$ for each pair of courses were achieved in the following results of p values (with complementing information about the effect size in case of rejecting the zero hypothesis): $p_{12} = .11 > .05$ (testing criterion $W = 88.50$, $5H_0$ fail to rejected for 1st and 2nd courses), $p_{13} = .04 < .05$ (testing criterion $W = 108$, $5H_0$ rejected in favor of $5H_1$ for 1st and 3rd courses with large effect size $r = .90$) and $p_{23} = 3.80 \times 10^{-3} < .05$ (testing criterion $W = 124$, $5H_0$ rejected in favor of $5H_1$ for 2nd and 3rd courses with large effect size $r = 1$).

4. Discussion of Achieved Results

In the university environment, the 3 mathematical courses were analysed by the methods of the testing the hypotheses, by the descriptive approaches, by the cluster analysis and time-based analysis of the attendances of the full-time students of the mathematical study field at the Faculty of Education at the University of Ostrava. The realization of this type of the quantitative analyses can be seen in the field of the university education with the consideration of the statistical significance e.g. in other research (Cieslar et al., 2020; Sikorova et al., 2019b).

Currently, the research topic occurred in the field of the education has been focused on the phenomenon of the students approaches to study since the spring 2020. As can be seen e.g. in (Jawad & Shalash, 2020), the impact of e-learning strategy on students' academic achievement is based on the existence of statistically significant relations between established researched aspects of the achieving objectives.

In this paper, due to the occurred pandemic situation, the following results were identified including the consideration of the statistical significance:

- (Answer to RQ1) The linear ratio of dependences was identified between all the total sums of the logins across all courses to each other. The lower resp. the higher frequency of approaches was consistent across behaviour of students.
- (Answer to RQ2) At one of the 3 pairs of considered courses (at 1st and 2nd course), the statistically significant paired similarities were identified between measured sums of students' logins to the considered pairs of courses.
- (Answer to RQ3) There are the statistically significant dependences of the total sums of logins on the concrete character of the considered mathematical course. According to the medians, it can be estimated, that the most difficult course is the 3rd course of the synthetical geometry.
- (Answer to RQ4) There are statistically significant dependences of the unified study fields on the total sums of the logins of the students across the courses.
- (Answer to RQ5) At one of the 3 pairs of considered courses (at 1st and 2nd course), the statistically significant paired similarities were identified between summed values of the discrete autocorrelation functions to the considered pairs of courses.

In general, the possible difficultness of the course of the synthetical geometry could be the reason of often appeared visits of the courses by the students on the statistical significance level 0.05. In the structure of the study fields, the similarities were identified. The descriptive analysis (averages, medians, standard deviations), analysis of similarities (cluster analysis) or Chi-squared test of the homogeneity of the appeared results, time-based data analysis – all presented analyses keep the same trend of conclusions obtained by the answers to the research questions. In this quantitative research, the significance of the topic of the geometry, e.g. seen also in Korenova (2017), was proven on the examined file of students of the study field of the preparing the future mathematical teachers.

5. Conclusion

In this article, the particular quantitative analysis of the accessing the mathematical study sources was presented. The considered educational strategies were based only on the essential accesses to the e-learning system Moodle. The achieved results of the proposed quantitative analysis of the students' approaches to the e-learning can be advantageous for the other academics with regards to the experiences with the occurred pandemic situation in the world. The consideration of the statistical significance can be appropriately used for purposes of the possible inductions of the presented analysis. Moreover, the presented time-based analysis of the serialized data can be further inspired in the potential occurred situation in the future in the sense – how often could be the courses visited by the students in the real situations with regards to the possibilities of the students. In the frame of the distance learning, the difficultness of the courses can influence the interest of the students in favor of the visiting the courses, as was proven on the significance level by the course of the synthetical geometry in this article.

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