I.J. Modern Education and Computer Science, **2022, 6, 25-34**
Published Online on December 8, 2022 by MECS Press (http://www.mecs-press.org/)
DOI: 10.5815/ijmecs.2022.06.03

Analysis of the Results of the Pedagogical Experiment on the Integrated Analysis of the Average and Dispersions

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Received: 04 June, 2022; Revised: 16 August, 2022; Accepted: 18 November, 2022; Published: 08 December, 2022

Abstract: Pedagogical scientists often need to process the results of a pedagogical experiment. However, not every scientist (especially in humanitarianism) has appropriate mathematical training, so statistical data processing is a problem for him. Scientists-pedagogues in Ukraine use various statistical methods to process the results of a pedagogical experiment and face the problem of cumbersome calculations and the accuracy of assessments. Therefore, we developed a method that is based on the correct mathematical apparatus, simplifies the processing of empirical data, and allows us to draw qualitative conclusions without the explicit use of mathematical apparatus. To simplify the statistical analysis of the results of the pedagogical experiment and the interpretation of the obtained data, the authors suggest using a spreadsheet and analyzing the data according to Student's and Fisher's criteria (comparing the average sample and its variance) and controlling intermediate indicators of the results of the pedagogical experiment. The method developed by the authors has an advantage compared to other methods: it is enough to analyze the pair "mean and variance" for the sample to conclude the significance of the differences in the control and experimental groups. The method has a simple implementation since almost every researcher has a spreadsheet processor on his computer. The method does not require a thorough knowledge of the statistics course. The method guarantees more reasonable conclusions (two criteria are used at once), which is important when conducting a pedagogical experiment.

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Index Terms: Pedagogical experiment, pedagogical research, statistical methods, integrated analysis of the average and dispersions, experimental model, specialist training.

1. Introduction

Many years of research experience in pedagogical science draw attention to the monotony of applying the methods of mathematical statistics to analyze the results of pedagogical experiments. Among the methods that are widely used, we note the Student's test for estimating the means, Pearson's chi-square test for comparing distributions in two samples, the Kolmogorov-Smirnov test, the sign test, etc. At the same time, pedagogical research often pursues the goal of improving the quality of education, and therefore, in most cases, teachers use only the assessment of averages, which does not always allow us to draw the right conclusions.

Also, quite often, only a percentage analysis of the data obtained in a pedagogical experiment is carried out, without accompanying statistical analysis, which would scientifically confirm or refute the significance of changes. In addition, many scholars in the field of pedagogy do not have deep mathematical knowledge and therefore cannot conduct a qualitative statistical analysis on one's own.

This becomes an obstacle to an in-depth analysis of the experimental results obtained during the study. On the other hand, there are many scientific works, which, on the contrary, are oversaturated with mathematical formulas to substantiate the proposed approach. Such works are difficult to perceive or even rejected by teachers and educators. Therefore, such methods of analyzing the results of a pedagogical experiment become relevant, which are based on statistical analysis and allow drawing reliable conclusions but do not require the explicit use of mathematical apparatus and cumbersome calculations.

After analyzing scientific works in the field of pedagogy and analyzing the statistical methods for evaluating the results of a pedagogical experiment that were used in them, we concluded that it is necessary to use: 1) computer tools to simplify calculations and 2) methods that would give a transparent assessment in the interpretation of the result.

Today there are many specialized programs for statistical data processing (SPSS, Stats, Statistical Calculator, Maple, Wolfram Mathematica, GeoGebra, etc.), but for a non-specialist, they are difficult to use and most are paid. Therefore, our choice is to use a spreadsheet processor (for example, MS Excel), which, as a rule, is installed on every computer with an office suite.

To simplify the perception of empirical data, we decided to use the sample Average (arithmetic mean over all sample values) and the Dispersion as the square of the standard deviation (the value of the spread of values around the mean). To calculate these characteristics, the spreadsheet processor has built-in tools. As criteria for the significance of changes in such characteristics of the sample as the Average and Dispersion, we chose the classical Student's test (test for comparing averages) and Fisher (test for comparing dispersions). Our approach to evaluating the results of a pedagogical experiment is reduced to the simultaneous evaluation of two indicators: the mean and the variance. We believe that it is the simultaneous use of such criteria at the beginning, at intermediate stages, and at the end of the experiment that provides a deeper and more reliable interpretation of the data obtained.

2. Literature Review

Mathematical statistics has a significant number of criteria designed to test a variety of statistical hypotheses. As a rule, hypotheses concern either the law of data distribution in the sample (normal, binomial, etc.) or the numerical characteristics of the sample (means, variance, correlation, etc.) [15], which describes the use of criteria for the normal distribution law.

There are also several non-parametric methods for statistical evaluation of results (Wilcoxon-Mann-Whitney test, Spearman test, etc.) [6].

The most developed theory is to test hypotheses about the numerical characteristics of the normal distribution law. Verification of averages in two samples is carried out using the t-test (Student) [5].

Pearson’s, Student’s, and Fisher’s criteria are used to compare/contrast distributions in two samples (usually control and experimental groups) [12].

When evaluating production, medical, pedagogical, and other management decisions, hypotheses about the numerical characteristics of the sample of control and experimental groups are usually used. In scientific and pedagogical research, the average scores are often compared or the significance of changes in learning outcomes is investigated, for which the Student’s criterion of assessment of averages or non-parametric criterion of signs is used [5, 6]. Sometimes, the authors stop at the analysis of the percentage distribution of individual characteristics of students [2, 7, 10] and do not conduct a statistical analysis of the results.

The development and dissemination of digital technologies have become an effective lever in creating effective and convenient tools for statistical analysis of pedagogical research. O. Spirin, T. Novitska, and A. Yatsyshyn emphasize the importance of using electronic library databases in such research [21].

General approaches to evaluating the effectiveness of pedagogical research using information and digital technologies were studied by S. Novitsky. He analyzed the effectiveness of empirical and theoretical approaches in the context of monitoring and analysis of scientific and educational work [13].

M. Shyshkina analyzes the tools of computerization of statistical and analytical research [20].

W. Rogers, H. Morris-Matthews, J. Romig, and E. Bettini propose to improve the method of observation in the educational process using information technology, in particular, to prove its reliability and validation [19].

Methods of empirical illustration of pedagogical research and methodological review of digital resources for their implementation are offered by A. Katrin [1].

Often scientists who do not have a deep mathematical education are guided by works where examples explain the peculiarities of testing the results of a pedagogical experiment on one or another criterion. Among such works we consider the most common:

- work [4], which outlines a significant number of statistical methods that should be used in psychological and pedagogical research. The authors of G. Glass, J. Stanley, set the following goal: first, to teach them to understand research reports in scientific papers, provided they are familiar with the problem being studied; second, to learn to plan research and analyze the results using a reference book. Scientists considered the first goal to be the main one [4]. Indeed, it is impossible to carry out own research, and the main thing – is to understand the results of the received statistical characteristics. The book is a handy textbook for training future teachers in the non-humanitarian field of training;
- work [4], which provides brief theoretical information on the use of the most common statistical criteria based on non-parametric methods of sample evaluation. The authors note that any presentation of a general theory of statistical hypothesis testing inevitably involves very serious mathematical training, which is not possessed by most research educators, and therefore consider a large number of typical studies and statistical criteria that should be used;
- work [6], which describes typical cases of using statistical methods in pedagogical research. The author gives “recipes” for the use of statistical methods in typical cases of analysis of experimental data on the results of pedagogical research, provides an algorithm for selecting statistical criteria, and methods for determining statistical similarities and differences in characteristics of the studied objects. The work is designed for teachers-researchers, primarily for graduate students and applicants [6];
- manual [5] contains methodological advice for young scientists on the organization of pedagogical experiments, the algorithm of their implementation, as well as offers options for statistical analysis of the results of pedagogical experiments.
- manual [15], which describes the use of criteria for the normal distribution law;
- online resources for automation of calculations, for example, to determine the coefficient of linear pairwise correlation Pearson [9, 17].

It should be noted that with the development of information technology, a lot of computer programs have appeared, where developers provide tools to support statistical calculations. Among them: are Statistica, Maple (stat subpackage), GeoGebra, MS Excel (statistical functions and Analysis package), etc. With the correct interpretation of commands (computer tools), it becomes possible to quickly process cumbersome mathematical formulas and simplify calculations (for example, [3]). And then it becomes important not so much the ability to write a formula, but the awareness of hypotheses and the correct perception and interpretation of the result.

Thus, some conditions allow researchers with a liberal education to conclude without complex mathematical calculations. The purpose of our study is to propose such an approach (method) to the statistical analysis of the results of a pedagogical experiment, which would require knowledge of only an initial course in statistics (understanding the sample, sample size, population, mean, variance, standard deviation), and which should become the basis for qualitative analysis and reasoned conclusions.

3. Background

Here is a typical algorithm for testing the statistical hypothesis:

(1) At the first stage, samples are formed for a certain indicator (observation).
(2) The null hypothesis H_0 and the alternative hypothesis H_1 are formulated. The null hypothesis is tested using a specially selected random variable, the exact or approximate distribution of which is known in advance.

The statistical criterion K_n is chosen. To test the null hypothesis according to the sample data, the observed (empirical) value of the criterion with a given level of significance is calculated (for pedagogical sciences, a reliable probability of 0.95 or a significance level of 0.05 is accepted). Critical and empirical meanings are compared. If the empirical value of the criterion falls into the critical area (Fig. 1), hypothesis H_0 is rejected in favor of the alternative hypothesis H_1.

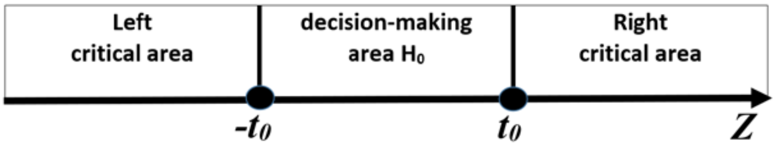


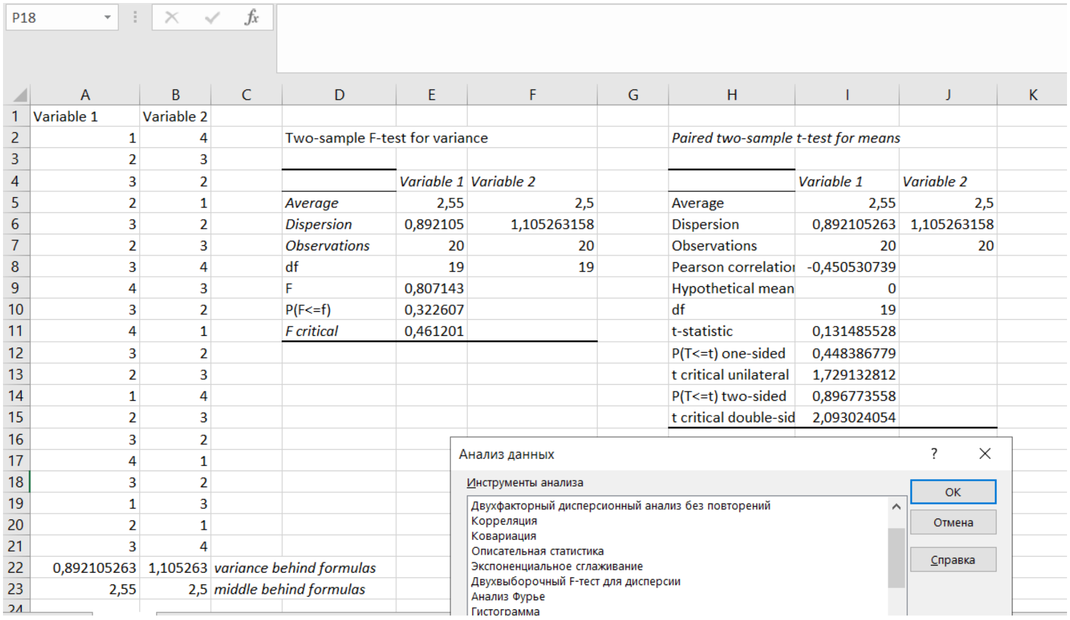
Fig. 1. Areas for accepting hypotheses

Hypothesis testing can solve, first of all, the problem of comparing sample numerical characteristics (averages, variances) with the corresponding specified values, and numerical characteristics of two or more samples among themselves (testing the hypothesis that these samples belong to one set).

Testing statistical hypotheses about the equality of means are based, for example, on the algorithm of the Student's test, and on the equality of variances – on the algorithm of the Fisher test.

These criteria are embedded in most specialized computer programs, which automates the calculation of both the critical value of the criterion and the empirical value of statistics on this criterion.

As an example, we give calculations in the MS Excel spreadsheet, which is installed on almost every computer (Fig. 2).



	A	B	C	D	E	F	G	H	I	J
1	Variable 1	Variable 2								
2	1	4		Two-sample F-test for variance				*Paired two-sample t-test for means*		
3	2	3								
4	3	2			*Variable 1*	*Variable 2*			*Variable 1*	*Variable 2*
5	2	1		*Average*	2,55	2,5		Average	2,55	2,5
6	3	2		*Dispersion*	0,892105	1,105263158		Dispersion	0,892105263	1,105263158
7	2	3		*Observations*	20	20		Observations	20	20
8	3	4		df	19	19		Pearson correlatioı	-0,450530739	
9	4	3		F	0,807143			Hypothetical mean	0	
10	3	2		P(F<=f)	0,322607			df	19	
11	4	1		*F critical*	0,461201			t-statistic	0,131485528	
12	3	2						P(T<=t) one-sided	0,448386779	
13	2	3						t critical unilateral	1,729132812	
14	1	4						P(T<=t) two-sided	0,896773558	
15	2	3						t critical double-sid	2,093024054	
16	3	2								
17	4	1								
18	3	2								
19	1	3								
20	2	1								
21	3	4								
22	0,892105263	1,105263	*variance behind formulas*							
23	2,55	2,5	*middle behind formulas*							

Fig. 2. Example of calculations in MS Excel

Statistical analysis of two sample data (columns A and B) can be performed using the optional *Data/Analysis Package*, which includes the *Two-sample F-test for variance* and *Pair two-sample t-test for means*. These tools, as a result, tables of sample characteristics are formed:

- for Fisher's test – mean value, variance, sample (observation) size, number of degrees of freedom (*df*), an empirical value of statistics (*F*), and critical value of statistics ($F_{critical}$);
- for Student's t-test – mean, variance, sample (observation) size, the correlation coefficient for the data set (Pearson correlation), the hypothesis-specified difference between the means for two samples (hypothetical difference), number of degrees of freedom (*df*), an empirical value of the statistic – statistic) and the critical value of the statistic (*t* is critical for one-sided and two-sided areas).

The researcher only needs to compare critical and empirical significance to conclude whether the null hypothesis is accepted or rejected. For the example shown in the figure (Fig. 2), we have:

- to compare the means, compare the empirical value of the statistic $t = 0.13$ (cell I11) and the critical value $t = 2.09$ (cell I15) and conclude that the sample data give reason to accept the null hypothesis ($0.13 < 2.09$) statistical equality of means is equal to zero);
- to compare variances, compare the empirical value of statistics $F = 0.80$ (cell E9) with the critical value $F = 0.46$ (cell E11) and conclude that the sample data give reason to reject the null hypothesis ($0.80 > 0.46$) in favor of the alternative (the variance is not equal to, and the difference is statistically significant).

In a pedagogical study, it is advisable to compare the average values and deviations at different stages of the pedagogical experiment to adjust the proposed teaching methods.

4. Methodology

To achieve the result, the following were used: theoretical analysis of scientific records by revealing the theoretical foundations of statistical analysis in pedagogical achievements; content analysis of Internet resources by the method of resource allocation for the automation of statistical observations; empirical methods (pedagogical experiment) demonstrating the process of processing empirical data for a fragmented methodology.

In pedagogical research, experimental verification of the effectiveness of the author's methodological system (model, approach, etc.) involves the use of the normal distribution law. But approaches to comparing experimental data in the control and experimental groups require not only checking the normality of their distribution, but also a more detailed analysis, which concerns not only the mean value of the data (mean – mathematical expectations), but also the variance, which allows us to characterize the values of the sample variance around its average value (standard deviation) and, if additionally taken into account, it becomes possible to deepen the analysis of the data obtained and more reasonable conclusions about the stability of the studied parameters and their prediction.

Therefore, our approach to the statistical analysis of the results of a pedagogical experiment is based on two positions:

1) a comprehensive accounting of changes in the means and variances of both samples: the idea is to simultaneously analyze the samples according to the Student and Fisher criteria, compare the means and variances, and draw appropriate conclusions about the effectiveness of the author's model or approach;

2) tracking the intermediate results of the pedagogical experiment for timely adjustment of the developed methodology or approach: the idea is that, first of all, the pair "control group and experimental group at the clarifying stage of the experiment" is monitored, the methodology is improved (or not), and the new paired group and experimental group at the stage of experiment formation "the author's method is finally confirmed.

To study the results of the pedagogical experiment, the following algorithm of actions is proposed, which simplifies the analysis and at the same time relies on the mathematical apparatus and gives reasonable conclusions.

(1) At the beginning of the pedagogical experiment, we form groups: ($\overline{Z}$ – average for KG, ${S_z}^2$– variance for KG) as a control; EG-1 ($\overline{Y}$ – average for EG-1, ${S_y}^2$ – variance for EG-1) as experimental at the refinement stage of the experiment. Later we form the group EG-2 ($\overline{X}$ – average for EG-2, ${S_x}^2$ – variance for EG-2) as experimental at the formative stage of the experiment.
(2) The groups are selected so that at the entrance of the experiment they are homogeneous in composition concerning the indicator under study (for example, the results of tests or survey results). Such verification is carried out in advance, for example, using the chi-square criterion [6].
(3) Set the significance level (usually 5% or 0.05).
(4) We record the results of the studied indicator for each of the samples (ie we form samples).
(5) When using computer tools (in this case MS Excel) determine the results of the application of statistical criteria for estimating the mean (Student's criterion) and estimating variances (Fisher's criterion).
(6) Construct a table (Table 1): if the hypothesis H_0 is accepted, then enter the value 0 in the table (slight discrepancy or deviation in the results). If the alternative hypothesis H_1 is accepted, then we enter the value 1 in the table (significant discrepancies or deviations in the results). Fill the cells filled with blue.

Table 1. Significance of the difference between the mean and variance for a given indicator ("1" – significant deviation, "0" – non-significant deviation)

Indicator	**1**	**2**	**3**	**4**	**5**	**6**
	$\bar{X}$	$\bar{X}$	$\bar{Y}$	S_x^2	S_x^2	S_y^2
	$\bar{Y}$	$\bar{Z}$	$\bar{Z}$	S_y^2	S_z^2	S_z^2
Indicator –1						

(7) Carry out a qualitative analysis of the results, ie compare the corresponding pairs "evaluation of samples by Student's test" (one of the columns 1-3 of table 1) and "evaluation of samples by Fisher's test" (one of the columns 4-6 of table 1), which can be in variations:

a. "0 (for averages) and 0 (for variances)" – means that the averages are statistically the same and the variances are statistically the same, which leads to the conclusion that there is no impact of the developed methodology (or approach) on the studied indicator;

b. "0 (for averages) and 1 (for variances)" – means that the averages are statistically the same and the variances are statistically different, which leads to the conclusion that there is no difference in the variance of the impact of the developed methodology (or approach) on the studied indicator. If the variance is greater in the experimental group, the reasons should be clarified and the methodology should be improved or abandoned;

c. "1 (for averages) and 0 (for variances)" means that the averages are statistically different and the variances are statistically the same, which leads to the conclusion about the existing, statistically significant impact of the developed methodology (or approach) on the studied indicator. It is necessary to assess the progress (dynamics) of the averages for a qualitative and correct conclusion about the effectiveness or vice versa (negative impact) of the implemented methodology;

d. "1 (for averages) and 1 (for variances)" means that the averages are statistically different and the variances are statistically different, which leads to the conclusion of significant differences in the experimental and control groups, which usually indicates in favor of the experimental group and proves the positive impact of the proposed method (or approach) on the studied indicator. It is important to assess not only the dynamics of the means (increases or decreases) but also to compare variances: if during the experiment the variance decreases, it further indicates the quality of the impact of the developed methodology (or approach); if the variance increases, it means that with the change of the mean the scatter of estimates around the mean increases, ie in the experimental group the perception (and influence) of the chosen technique is ambiguous, which also requires some adjustment of the latter.

The results' accuracy and reliability are based on using the correct mathematical apparatus and a clear interpretation of the results of applying the Student and Fisher criteria. Experimental data are collected and entered into the tables by the experimenter. Calculations are carried out automatically. Pairs are interpreted by the experimenter according to the specified rule-algorithm.

5. Results

We describe the use of the above algorithm in the example of processing the results of one of the stages of the pedagogical experiment.

Mathematics education is the basis of the system of professional training of future specialists in computer engineering in technical higher educational institutions. Therefore, the effectiveness of the author's system of teaching higher mathematics to future computer engineers was tested.

For the pedagogical experiment the control group was selected – *KG* ($\overline{Z}, {S_z}^2$), the group *EG-1* ($\overline{Y}, {S_y}^2$) – clarifying experiment and the group *EG-2* ($\overline{X}, {S_x}^2$) – a formative experiment.

Table 2. Significance of differences in indicators of numerical characteristics of knowledge formation in groups K, E, and F ("1" – significant deviation, "0" – non-significant deviation)

№	Section	1		2		3		4	5	6	7	8	9
		EG-2		EG-1		KG		$\overline{X}$	$\overline{X}$	$\overline{Y}$	S_x^2	S_x^2	S_y^2
		$\overline{X}$	S_x^2	$\overline{Y}$	S_y^2	$\overline{Z}$	S_z^2	$\overline{Y}$	$\overline{Z}$	$\overline{Z}$	S_y^2	S_z^2	S_z^2
1	**Linear algebra**	**4.06**	**0.79**	**3.94**	**0.75**	**3.08**	**0.96**	**0**	**1**	**1**	**0**	**1**	**1**
2	Vector algebra	3.99	0.28	3.63	0.32	2.78	0.58	1	1	1	0	1	0
3	Analytical geometry	3.81	0.57	3.78	0.98	2.59	0.80	0	1	1	0	1	0
4	Differentiation of functions	4.12	0.56	4.08	0.48	3.50	0.86	0	1	1	0	1	1
5	Defined integral	3.96	0.35	3.47	0.90	3.44	1.01	1	1	0	1	1	0
6	Multiple and curvilinear integrals	3.67	0.79	3.40	0.72	3.11	0.34	1	1	1	0	1	1
7	Differential equations	3.63	0.69	3.51	0.73	2.83	0.77	0	1	1	0	1	1
8	Theory of numerical and functional series	3.46	0.82	3.18	0.89	2.84	0.90	1	1	1	1	1	0
9	Functions of a complex variable	3.52	0.98	3.12	0.99	2.94	0.99	1	1	0	1	0	0
10	Operating calculus	3.46	0.78	3.40	0.81	3.10	0.93	0	1	0	0	1	0
11	Probability theory and mat. statistics	4.35	0.83	4.13	0.63	3.13	0.50	0	1	1	1	1	1

Among others, the "Knowledge" indicator was studied based on final tests in various sections of higher mathematics. The results of the control works formed samples that were compared among themselves according to the algorithm. We evaluated each control work in 5 points. The average and dispersions for each sample of EG-2, EG-1, and KG were entered in the corresponding cells (in particular, these are columns with numbers 1.1, 2.1, 3.1 for averages, and 1.2, 2.2, 3.2 for variances). The results of the comparison of pairs of groups according to the Student and Fisher criteria were entered in the right part of the table (blue fields). Columns 4-6 show the results of the evaluation of pairs of samples according to the Student's criterion. Columns 7-9 show the results of the estimation of pairs according to Fisher's test. (Table 2)

To understand the interpretation of the data, let's comment on the first line of the table corresponding to the course "Linear Algebra" (highlighted in bold).

Students (KG, EG-1, EG-2) wrote a test paper for which they received certain marks. Means and variances were determined for each group: for example, for the KG group, the mean was 3.08, and the variance was 0.96. After that, the Student's test is applied to each of the pairs of groups (in MS Excel) and a conclusion is made about the statistical similarity or difference of the means. For the pair EG-2 and EG-1, the criterion gave statistical similarity, so for this pair we put "0" (column 4), and for the pair EG-2 and KG, the criterion confirmed a statistical discrepancy, so we put "1" (column 5). Similarly, we apply Fisher's criterion (calculated automatically in MS Excel). For the pair of EG-2 and EG-1, the criterion again gave statistical similarity, therefore, for this pair we put "0" (column 7), and for the pair of EG-2 and KG, the criterion confirmed a statistical discrepancy, so we put "1".

To interpret the data, we compile the corresponding pairs of "averages and variances" based on the results of statistical analysis:

- For groups EG-2 and EG-1 we have a pair of "0-0" (column 4 and column 7). This means that there was no shift in learning outcomes for these samples;
- For groups EG-2 and KG we have a pair "1-1" (column 5 and column 8). This means that a shift in learning outcomes for these samples has occurred. Therefore, means and variances should be compared. The average in EG-2 is 4.06 (column 1.1). It is greater than the average in KG (3.08, column 3.1). This means that the influence of the method on educational achievements according to the analysis of averages should be considered positive. But this conclusion will be more valid if it is confirmed that the spread of grades for control works in the experimental group is smaller (that is, all grades are closer to the average than in the KG). Let's compare the variances of these samples. In the EG-2 group, the variance is smaller (0.79, column 1.2) than in the KG group (0.96, column 3.2). We conclude that the impact of the methodology was positive, and the learning results in the EG-2 group are higher and more reliable, as they have less dispersion (the average is higher and the variance is smaller).

The analysis of the significance of the differences between the means and variances between the groups shows that the proposed system of teaching mathematical disciplines significantly increases the level of knowledge acquired by students. This is evidenced by the data in columns 5 and 8. The indicator indicates a significant difference in students' knowledge of all topics in favor of the proposed system. At the same time, the statistical average for all topics was higher in the experimental group of the formative stage.

After statistical processing of the results of the refinement phase of the experiment, we saw that although the test results in the experimental group EG-1 were higher than the results of the control group CG, the difference was not consistently significant (columns 6 and 9). This meant that this element in the training system did not affect the results we wanted. The method of lectures and practical classes on vector algebra, analytical geometry, definite integral, series theory, functions of a complex variable, and operational calculus was improved (changed) (in particular, author's textbooks were introduced, which provided independent processing of higher mathematics sections by students).

The results of statistical analysis after the formative experiment confirmed a positive shift in the results of knowledge acquisition after adjusting the methodology of classes, as evidenced by the data in columns 4 and 7 and 6 and 9.

Analyzing the obtained results of the significance of the difference in the indicators of numerical characteristics, we see that in all parameters the difference between the proposed system of teaching mathematical disciplines and traditional is significant. The difference between the values in the experimental group of shaping (EG-2) and refining (EG-1) experiments indicates that the decision to test it with a refining experiment and then conduct a shaper was correct.

6. Discussion

Features of the process of teaching and education are not easy to study and reveal. Pedagogical processes are ambiguous. Their results depend on the simultaneous influence of many factors. It is enough to change the influence of one factor so that the results of the process differ significantly from each other. The pedagogical processes are characterized by uniqueness. If a researcher of natural sciences (in chemistry, physics) can repeat the experiment several times, using the same materials, creating the same conditions, the teacher-researcher does not have such an opportunity: re-research offers different working conditions and as a result - other results. That is why a "pure" experiment in pedagogy is impossible. Given this circumstance, teachers should draw their conclusions carefully and thoughtfully, understanding the relativity of the conditions in which these conclusions were obtained. Multiple observations (repetition of the experiment) allow in a generalized form to formulate conclusions and identify the most characteristic trends [11]. It is this thesis that led to the intermediate pedagogical experiment, which is the basis of our methodology of statistical analysis.

The idea of the proposed algorithm of statistical analysis appeared in 2008 [14] in developing and improving the model of professional training of future specialists in technical specialties.

Its further use can be found in the works [8, 16, 18].

It should be noted that the method does not require separate verification, as it is based on proven methods of statistical analysis and at the same time simplifies the interpretation of the results of the pedagogical experiment for specialists in humanitarian specialties.

The authors of the article use the developed algorithm to determine the effectiveness of innovative teaching methods in various educational institutions in Ukraine. As practice shows, the results of the analysis testify to the effectiveness of the method.

7. Conclusions

The proposed algorithm of statistical analysis of the results of pedagogical experiments not only automates the calculations but also has an advantage over other statistical methods. The researcher only needs to analyze the tabular pairs of means and variances about the significance of the differences and draw conclusions.

The method has a simple implementation since almost every researcher has a spreadsheet processor on his computer.

The method does not require a thorough knowledge of the mathematical statistics course.

The method guarantees more well-founded conclusions (two criteria are used at once), as it takes into account two parameters, in particular the spread of grades, which is important in the process of analyzing the results of a pedagogical experiment.

We see the implementation of the algorithm in scientific and pedagogical practice as promising, as well as the writing of a macro that automates the filling of the table based on the data entered in three samples.

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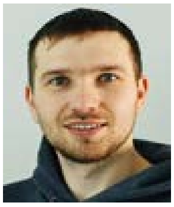

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How to cite this paper: Vira Petruk, Yuliia Rudenko, Artem Yurchenko, Inna Kharchenko, Serhii Kharchenko, Olena Semenikhina, "Analysis of the Results of the Pedagogical Experiment on the Integrated Analysis of the Average and Dispersions", International Journal of Modern Education and Computer Science(IJMECS), Vol.14, No.6, pp. 25-34, 2022. DOI:10.5815/ijmecs.2022.06.03