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Univariate Analysis of Variance as a Method of Solving Professional Pedagogical Tasks in Higher Education

Abstract. Introduction*. The new challenges facing the world community in the context of post-industrial development bring to the fore the problems of human capital development. Thus, education plays a key role in ensuring the social and economic well-being of each individual, each country and the world community as a whole. In our opinion, the achievement of this goal will be possible in the case of skillful application of modern didactic methods, not simple exercises, but real pedagogical tasks – tasks of a high level of complexity by lecturers. Professional pedagogical activity is defined as a constant process of solving pedagogical problems, so lecturers should pay considerable attention to the technology of their solution.*

Purpose. *The purpose of this publication is to reveal and clarify the meaning of the term "professional pedagogical task" in the context of the method of its solution in higher education establishment.*

Results. *The article presents, using a practical example, the method of using one-factor variance analysis in solving professional problems of higher school teachers, in particular, identifying the main factors influencing the success of students in higher education institutions. The main purpose of variance analysis is to statistically reveal the influence of various factors on the variability of the characteristic being studied. Of particular interest is the use of the method in the analysis of economic processes and phenomena, when the variability of the resulting characteristic is caused by the simultaneous action of several factors with unequal influence. In particular, this is observed when analyzing the effective synthetic indicators of the economic efficiency of production.*

Conclusions. *Our research material makes it possible to justify the choice of univariate analysis of variance for its application in solving professional pedagogical problems of teachers in higher educational institutions. The results of data processing using analysis of variance give a quantitative or qualitative assessment of research, which, in turn, increases the efficiency of the educational process, improving it.*

Keywords: *univariate analysis of variance; professional pedagogical problem; data processing; higher education.*

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Однофакторний дисперсійний аналіз як метод розв'язування професійних педагогічних задач у вищій школі

Нові виклики, що постають перед світовою спільнотою в умовах постіндустріального розвитку, висувають на перший план проблеми розвитку людського капіталу. Таким чином, освіта відіграє ключову роль у забезпеченні соціального та економічного добробуту кожної людини, кожної країни та світової спільноти в цілому. На нашу думку, досягнення цієї мети стане можливим за умови вмілого застосування викладачами сучасних дидактичних методів, не простих вправ, а справжніх педагогічних завдань – завдань високого рівня складності. Професійно-педагогічна діяльність визначається як постійний процес вирішення педагогічних завдань, тому значну увагу викладачі повинні приділяти технології їх вирішення.

Метою публікації є розкриття та уточнення змісту поняття «професійно-педагогічна задача» в контексті методики її вирішення у закладі вищої освіти.

У статті на практичному прикладі представлена методика застосування однофакторного дисперсійного аналізу у розв'язанні професійних задач викладачів вищої школи, зокрема, виокремлення основних факторів впливу на успішність здобувачів у закладах вищої освіти. Головне призначення дисперсійного аналізу – статистично виявити вплив різних факторів на мінливість ознаки, що вивчається. Особливий інтерес становить використання методу в аналізі економічних процесів та явищ, коли мінливість результативної ознаки зумовлена одночасно дією кількох факторів із неоднаковою силою впливу.

Матеріал нашого дослідження дає змогу обґрунтувати вибір однофакторного дисперсійного аналізу для його застосування при розв'язанні професійно-педагогічних завдань викладачів закладів вищої освіти. Результати обробки даних за допомогою дисперсійного аналізу дають кількісну або якісну оцінку дослідження, що, своєю чергою, підвищує ефективність освітнього процесу, покращуючи його.

Ключові слова*: однофакторний дисперсійний аналіз; професійно-педагогічна проблема; обробка даних; вища освіта.*

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Formulation of the problem. The new challenges facing the world community in the context of post-industrial development bring to the fore the problems of human capital development. Thus, education plays a key role in ensuring the social and economic well-being of each individual, each country and the world community as a whole. In our opinion, the achievement of this goal will be possible in the case of skillful application of modern didactic methods, not simple exercises, but real pedagogical tasks – tasks of a high level of complexity by lecturers. Professional pedagogical activity is defined as a constant process of solving pedagogical problems, so lecturers should pay considerable attention to the technology of their solution.

Analysis of recent research and publications. In the educational process, the lecturer constantly has to deal with the solution of various pedagogical situations, so his professional activity can be considered as the art of solving them. The analysis of scientific works due to the research problem showed that the works of N. V. Bordovska [12], G. O. Ball [2], M. Bond, K. Buntins, S. Bedenlier [18] are devoted to the theoretical bases of solving pedagogical problems; O. V. Akimova [1] studied the formation of creative thinking in the process of solving mental problems and analyzed the psychological features of teachers' thinking; I. M. Melnykova, Yu. M. Kravchenko [8] searched the methods of solving pedagogical problems ; the works of M.V. Kuzmina [7], L. O. Milto [9], L. F. Spirin [15], O. A. Dubasenyuk [4], S. T. Shaw, A. A. Pogossian, G. Ramirez [17] are devoted to the technologies for solving pedagogical problems. However, there are no scientific works related to the formation of skills to solve pedagogical problems through analysis of variance.

The primary problem in solving pedagogical problems, according to Leontiev, is to find ways to solve them. According to S. U. Goncharenko: «The task is the purpose of activity given in certain conditions of process which should be reached by transformation of these conditions according to a certain procedure. The task includes a requirement (goal), conditions (known) and sought (unknown), which is formulated in the questions. Certain connections and dependences are formulated between these elements due to which search and definition of unknown elements is carried out»[3, p. 130]. The explanatory dictionary of the Ukrainian language defines the process as a consistent change of states or phenomena, which occurs in a regular manner; as the course of development of something; as a set of successive actions, means aimed at achieving a certain consequence [14, p. 343]. Investigating the process of solving problems G. O. Ball defined it as the impact on the subject of the problem, which determines its transition from the initial state to the necessary. Solved problem is a problem, the subject of which is translated into the desired state, ceases to be a task [2, pp. 34-35]. V. O. Slastyonin considers solving pedagogical problems as a way and as a process. A method of solving a problem is a system of successive operations (procedures) that lead to the solution of the problem. The solution of the pedagogical problem, in his opinion, can be described as the implementation of some method, as a «fragment of the functioning of the solver», carried out by him in solving the problem or in order to solve it [13]. N. V. Bordovska considers the process of solving pedagogical problems in the framework of pedagogical activities as a special type of activity in the system «man – man» [12, 18]. After analyzing different approaches to the definition of these concepts, we formulated a working definition of the process of solving pedagogical problems by high school lecturers as a set of interrelated actions based on subject-subject relations to achieve educational results, which is the formation of development skills to identify pedagogical tasks.

Formulation of research goals. The purpose of this publication is to reveal and clarify the meaning of the term “professional pedagogical task” in the context of the method of its solution in higher education establishment.

Outline of the main research material. After a thorough theoretical study of the object of study, it is necessary to obtain experimental data on the influence of current factors on the indicator that characterizes the object of study - the criterion. Thus, univariate analysis of variance in solving pedagogical problems significantly refutes the determination of the level of effectiveness of a particular method on student’s success. Consider this in the specific example.

In the era of rapid development of society, the use of mathematical statistics methods in scientific research becomes an urgent necessity. It must be admitted that the correlation-regression method has recently become widely used in multivariate analysis, while at the same time, a fairly effective method of statistical-mathematical processing of research data - variance analysis - is almost not used at all. Like other statistical methods, it greatly expands the possibilities in the analysis of production and significantly raises the level of scientific research.

The main purpose of variance analysis is to statistically reveal the influence of various factors on the variability of the characteristic being studied. Of particular interest is the use of the method in the analysis of economic processes and phenomena, when the variability of the resulting characteristic is caused by the simultaneous action of several factors with unequal influence. In particular, this is observed when analyzing the effective synthetic indicators of the economic efficiency of production.

The most effective here is simultaneous variance analysis of all selected factors – multifactor analysis. You

can make a pairwise comparison of factors, in which all others are ignored, but this approach to solving the issue does not make it possible to reveal the multiplicity of interaction effects that actually exists. In pedagogical research, one-factor variance analysis provides an opportunity to quantitatively measure the influence of factor characteristics and their combinations on the result; determine the probability of impact and its confidence intervals; to analyze individual averages and statistical evaluation of their difference.

It should be noted that in both pedagogical and economic research, the dispersion method has not yet gained such wide use as in biology and technology. Instead, the possibilities of its use in the spheres of pedagogy and economics are quite wide. The main purpose of variance analysis is to statistically reveal the influence of factors on the variation of the characteristic being studied. Of particular interest is the use of this method in those cases when the change in the mentioned characteristic is caused simultaneously by the action of factors whose share of influence is varied.

Like other statistical and mathematical methods, dispersion analysis is a purely technical means of scientific knowledge. And its use in the study of pedagogical processes presupposes knowledge, first of all, of the essence of the processes, an understanding of the cause-and-effect relationships between the studied phenomena, and the ability to highlight the most important aspects of the interrelated and mutually determined phenomena under study.

The variance analysis uses the property of the sum of squares of the central deviations. Its essence is that when several completely independent factors act at the same time and determine the general variability of the characteristic, then the sum of individual variances measuring their influence is equal to the total variance.

We identified teacher training as one of many factors that affects the success of students in higher mathematics. For this purpose, 4 associate professors with different theoretical and practical training were selected. In the higher educational institution where they work, 20 students were selected with the principle of randomization. The criteria for assessing students' knowledge were the number of solved problems in 2 hours, which, depending on the complexity, were assessed by a certain number of points. The obtained results are listed in the table (Table. 1).

Table 1. **Results of students' knowledge assessment**

Scores	The average value of the interval ($\bar{y}_i$)	Lecturers			
		$A(m_{1j})$	$B(m_{2j})$	$C(m_{3j})$	$D(m_{4j})$
0	0	0	0	0	0
0–4	2	0	0	1	0
4–8	6	1	4	5	4
8–12	10	2	10	9	7
12–16	14	10	6	5	6
16–20	18	7	0	0	3

Source: created by the author

m_{1j} ; m_{2j} ; m_{3j} ; m_{4j} – the number of students from academic groups where associate professors worked

A, *B*, *C*, *D*, who received y_{ij} points for solving problems.

Solution.1. Let's calculate group averages:

$$\bar{y}_1 = \frac{\sum y_{ij} \cdot m_{1j}}{\sum m_{1j}} = \frac{0 \cdot 0 + 2 \cdot 0 + 6 \cdot 1 + 10 \cdot 2 + 14 \cdot 10 + 18 \cdot 7}{0 + 0 + 1 + 2 + 10 + 7} = \frac{292}{20} \approx 15;$$

$$\bar{y}_2 = \frac{\sum y_{ij} \cdot m_{2j}}{\sum m_{2j}} = \frac{0 \cdot 0 + 2 \cdot 0 + 6 \cdot 4 + 10 \cdot 10 + 14 \cdot 6 + 18 \cdot 0}{20} \approx 10;$$

$$\bar{y}_3 = \frac{\sum y_{ij} \cdot m_{3j}}{\sum m_{3j}} = \frac{2 \cdot 3 + 6 \cdot 5 + 10 \cdot 9 + 14 \cdot 5}{20} \approx 10;$$

$$\bar{y}_4 = \frac{\sum y_{ij} \cdot m_{4j}}{\sum m_{4j}} = \frac{6 \cdot 4 + 10 \cdot 7 + 14 \cdot 6 + 18 \cdot 3}{20} \approx 12.$$

2. Calculate the total average

$$\bar{y} = \frac{m(\bar{y}_1 + \bar{y}_2 + \bar{y}_3 + \bar{y}_4)}{4m} = \frac{15 + 10 + 10 + 12}{4} = \frac{47}{4} \approx 12.$$

3. Calculate the factor, total and random variance. To do this, we can make a table (Table 2).

Factor variance $D_x^2 = \sum m(\bar{y}_i - \bar{y})^2$.

Since in our example m = 20 the value is constant for all groups, the factor variance will be equal to: $D_x^2 = 20 \cdot (9 + 4 + 4 + 0) = 340$.

Total variance: $D_y^2 = \sum\sum (y_{ij} - \bar{y})^2 m_{ij} = 1184$.

Random variance is calculated as the difference between total and factor: $D_z^2 = D_y^2 - D_x^2 = 1184 - 340 = 844$.

4. We define a correlation that shows what impact the level of lecturers' training has on the quality of students' knowledge:

$$\eta_x^2 = \frac{D_x^2}{D_y^2} = \frac{340}{1184} = 0{,}29 .$$

Table 2. **Data for calculating factorial, total and random variances**

Factors	$\bar{y}_i - \bar{y}$	$(\bar{y}_i - \bar{y})^2$	$y_{ij} - \bar{y}$	$(y_{ij} - \bar{y})^2$	m_{ij}	$\frac{(y_{ij} - \bar{y})^2}{m_{ij}}$
A	3	9	–12 –10 –6 –2 2 6	144 100 36 4 4 36	0 0 1 2 10 7	0 0 36 8 40 252
B	–2	4	–12 –10 –6 –2 2 6	144 100 36 4 4 36	0 0 4 10 6 0	0 0 144 40 24 0
C	–2	4	–12 –10 –6 –2 2 6	144 100 36 4 4 36	0 1 5 9 5 0	0 100 180 36 20 0
D	0	0	–12 –10 –6 –2 2 6	144 100 36 4 4 36	0 0 4 7 6 3	0 0 144 28 24 108
Total:						1184

Source: created by the author

5. The influence of other factors is determined by this correlation:

$$\eta_z^2 = \frac{D_z^2}{D_y^2} = \frac{844}{1184} = 0{,}71.$$

Thus, this indicator indicates a high degree of density between the level of student achievement and the level of theoretical and practical training of the lecturer.

6. We determine the probability of the influence of this factor (the level of lecturer's training) on student's success. First, we set the value of the ratio of factor and random variances per degree of freedom, i.e.

$$F_c = \frac{\sigma_x^2}{\sigma_z^2}.$$

The number of degrees of freedom in the complex is equal: $k_y = 80 - 1 = 79$; for factor variance $k_x = 4 - 1 = 3$; for random: $k_z = 80 - 4 = 76$.

In our example $\sigma_x^2 = \frac{D_x^2}{k_x} = \frac{340}{3} \approx 113{,}3$;

$$\sigma_z^2 = \frac{D_z^2}{k_z} = \frac{844}{76} \approx 11{,}2;$$

$$F_{c\partial} = \frac{\sigma_x^2}{\sigma_z^2} = \frac{113{,}3}{11{,}2} \approx 10{,}1.$$

7. According to the table of values of the Snedekor distribution we find the values $F_{ст}$ для $k_x = 3; k_z = 76$; at the level of significance $\alpha = 0{,}05$ $F_{ст}$ =2,76.

8. Let's compare $F_{сд}$ (actual, experimental) з $F_{ст}$ (tabular): $F_{сд}$ = 10,1;

$F_{ст}$= 2,76; $F_{сд} > F_{ст}$

So, with probability $P = 1 - \alpha = 1 - 0{,}05 = 0{,}95$ it can be argued that the quality of training of research and teaching staff significantly affects the success of students, because it is established that the results of lecturers from whose groups the samples were made, differ significantly.

Conclusions. Our research material makes it possible to justify the choice of univariate analysis of variance for its application in solving professional pedagogical problems of teachers in higher educational institutions. The results of data processing using analysis of variance give a quantitative or qualitative assessment of research, which, in turn, increases the efficiency of the educational process, improving it.

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