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QUALITY ASSURANCE OF PEDAGOGICAL RESEARCH THROUGH STATISTICAL ARGUMENTS

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Abstract. The quality of pedagogical research is determined by methodological rigor, the validity of the results and the scientific substantiation of the formulated conclusions. Statistical analysis is one of the essential tools that contribute to the verification of hypotheses, the reduction of subjectivity, the generalization of results and the substantiation of educational decisions. The paper describes the main criteria for ensuring the quality of research through statistical arguments, highlighting the importance of correctly building databases, comparing means, determining correlations between variables and arguing statistical significances. The stages and conditions necessary for the correct application of statistical methods in pedagogical research are analysed, and recommendations are formulated regarding the consolidation of the culture of evidence-based research.
Keywords: pedagogical research, statistical analysis, databases, comparison of means, correlation coefficients, statistical significance, validity.

ASIGURAREA CALITĂȚII CERCETĂRII PEDAGOGICE PRIN ARGUMENTE STATISTICE

Rezumat. Calitatea cercetării pedagogice este determinată de rigurozitatea metodologică, validitatea rezultatelor și fundamentarea științifică a concluziilor formulate. Analiza statistică reprezintă unul dintre instrumentele esențiale care contribuie la verificarea ipotezelor, reducerea subiectivismului, generalizarea rezultatelor și fundamentarea deciziilor educaționale. În lucrare sunt descrise principalele criterii de asigurare a calității cercetării prin argumente statistice, evidențiind importanța construirii corecte a bazelor de date, comparării mediilor, determinării corelațiilor dintre variabile și argumentării semnificațiilor statistice. Sunt analizate etapele și condițiile necesare pentru aplicarea corectă a metodelor statistice în cercetarea pedagogică, fiind formulate recomandări privind consolidarea culturii cercetării bazate pe dovezi.
Cuvinte-cheie: cercetare pedagogică, analiză statistică, baze de date, comparație de medii, coeficienți de corelație, semnificație statistică, validitate.

Introduction

The development of modern pedagogical research is closely linked to the use of statistical methods that allow the transformation of empirical observations into scientific evidence. In the context of increasing demands on the validity and reproducibility of

results, statistical argumentation becomes an indispensable condition for ensuring the quality of research.

Statistical analysis is not only a technical stage of data processing, which includes the meticulousness of completing databases and the performance of complex descriptive or inferential statistics, but a process that contributes to the verification of formulated research hypotheses, to reducing the influence of subjective factors and to the formulation of rigorous objective conclusions. Through the correct use of statistical methods (tests / criteria), pedagogical research acquires scientific character, credibility and practical relevance.

Therefore, the quality of pedagogical research is ensured by the fulfilment of the main statistical criteria and procedures applied in contexts appropriate to the experimental context and the correct interpretation of their results.

Statistical criteria for ensuring research quality

Just as, in general, statistics consists of a set of methods for obtaining and analysing data, it provides, according to A. Agresti and B. Finlay, in particular, "methods for design: planning data collection for research studies; description: totalizing data; inference: formulating predictions based on data" [1, p. 17]. Thus, statistical analysis contributes to: verifying research hypotheses; reducing subjectivity in the interpretation of results; increasing the objectivity of the conclusions; generalization of the results on the investigated population; basing educational decisions on empirical evidence.

And by using statistical arguments, pedagogical research becomes scientifically valid, credible, reproducible and applicable in educational practice.

The quality of research is directly influenced by the way in which empirical data are collected, organized, analysed and interpreted. Therefore, the statistical criteria that must be respected in the process of pedagogical research, identified from the specialized literature [2-5] and from the authors' analysis of some published researches, refer to:

1. Databases: objective and correct completion of the collected databases;
2. Comparison of means: identification and comparison of comparable variables;
3. Correlations of variables: scientific substantiation of the relationships between variables through correlation coefficients;
4. Statistical significances: argumentation of statistical significances through appropriate statistical tests and criteria.

Each of these criteria will be described in detail below.

1. Databases

With reference to databases, the aspects that will be addressed are: appropriate software tools, accurately completed databases, verification of data accuracy, and identification of the type of variable distributions (figure 1).

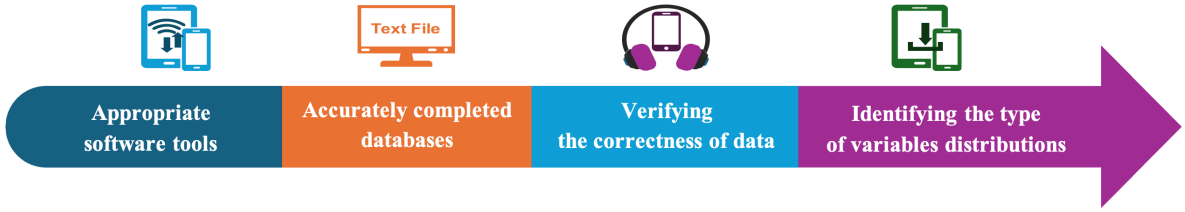


Figure 1. Aspects of qualitative database completion

For a qualitative completion of the databases collected in pedagogical research, the *use of appropriate software tools*, familiar to the researcher, will contribute to facilitating data processing and saving time for the study of a new and sophisticated tool. Statistical processing involves the correct use of specialized computer tools, and their choice must be made depending on the complexity of the research and the skills of the researcher. Among the most used tools are: SPSS [6]; Jamovi [7]; R language [8]; Python language [9] (figure 2) and so on. These applications offer the possibility of performing descriptive and inferential analyses, as well as the graphic representations necessary for interpreting the results. If the researcher has programming skills, then he can capitalize on these skills by using the Python or R programming languages [10], and if he has a socio-humanistic professional training, then specialized software applications in statistical processing such as the well-known SPSS or Jamovi [11] are appropriate.

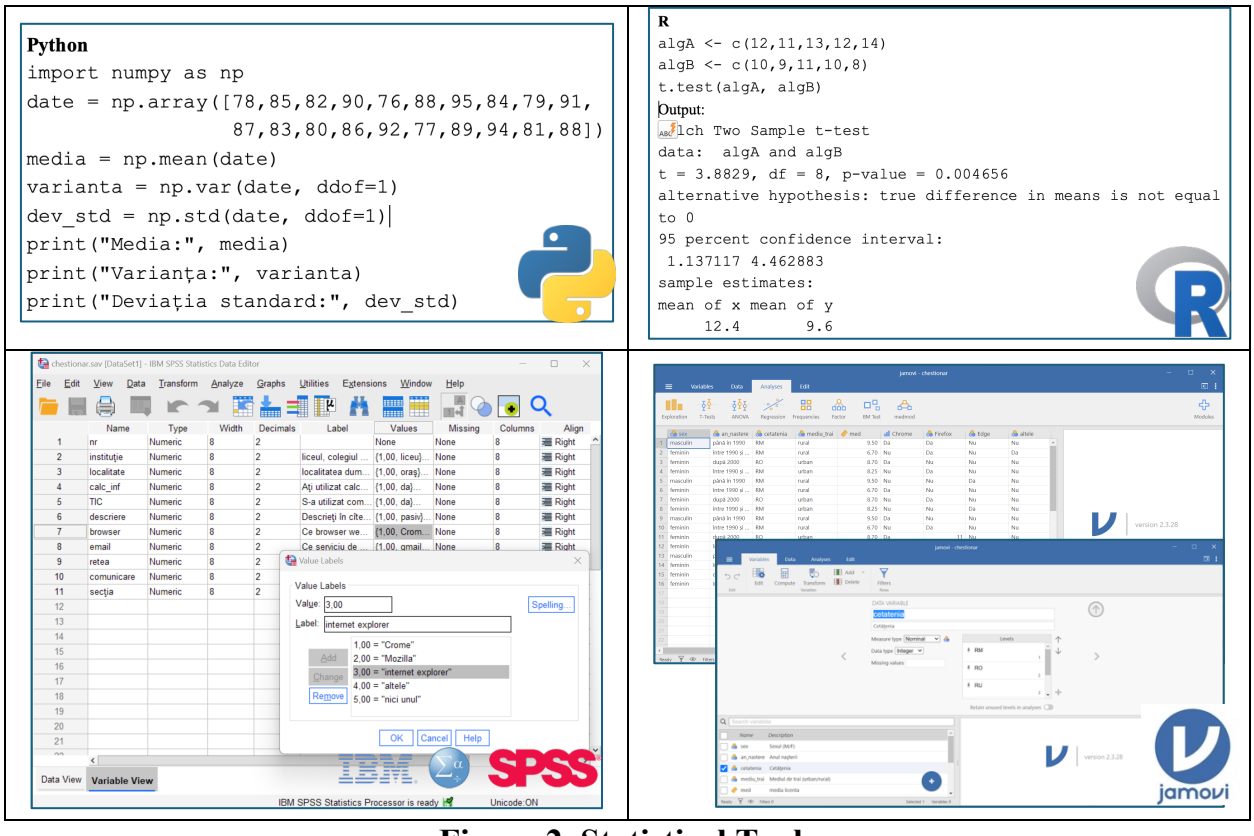


Figure 2. Statistical Tools

Regarding *the accurate completion of databases*, the first condition for obtaining valid results is the construction of complete and correct databases. The researcher must

record all the data collected, without arbitrary selections or unjustified eliminations of observations. The data entered must faithfully reflect the values obtained in the research process, and the structure of the database must allow for the clear identification of the variables and the investigated subjects. At the same time, the researcher's care for the measurement scale of the variables is also important, transposed into the subsequent identification of appropriate statistics and the avoidance of measurement errors.

Before performing statistical analyses, it is necessary *to verify the correctness and quality of the data* by:

- identification of missing values;
- elimination of incomplete records;
- detection of outliers;
- verification of data entry errors.

These operations contribute to increasing the fidelity and validity of the obtained results.

Another important aspect regarding databases is *the identification of the type of distributions of the variables* (normal distribution or deviations: skewness or kurtosis from the normal distribution). For quantitative variables it is necessary to verify the normality of the data distribution, because the results of this analysis determine the choice of appropriate statistical tests:

- parametric tests for normal distributions;
- non-parametric tests for asymmetric / abnormal distributions or for ordinal variables.

Confirmation or refutation of this condition, tested by graphical method (normality curve) or statistical method (Kolmogorov-Smirnov or Shapiro-Wilk tests, skewness and kurtosis coefficients), allows the performance of classical tests or the identification of alternative tests that satisfy the research conditions.

2. Comparison of means

Comparing means is one of the most common procedures used in pedagogical research to verify differences between groups. And a novice researcher and not only, can make a series of errors by comparing incomparable variables: measured on inadequate scales, coming from incomparable samples, or data series from completely different experimental contexts. Therefore, it is necessary to ensure the compatibility of variables by comparing only variables of the same type and measured on the same scale (nominal, ordinal, interval or ratio). Compliance with this principle prevents the formulation of erroneous conclusions.

In the context of *samples organizing*, to make comparisons, the data must be organized according to the analysed groups. The researcher can use separate databases for each sample, or organize output by groups through file splitting by the sample variable, depending on the context and his intention. For example, if the ANOVA analysis of

variances with repeated measures is desired, then it would be wrong to include the values of the subjects from different samples in the studied variables, because the conclusion would be erroneous. This is common case, given that at an initial stage of the study, samples mean are compared, which means that there is a grouping variable in the initially created database, and the application of the aforementioned statistical method requires a careful strategy, any errors being identified by the total number of subjects included in the test.

Regarding *the homogeneity of variances*, in the case of parametric tests, the verification of this criterion is an important condition. This is frequently performed by the Levene test. If the variances are homogeneous, classical statistical procedures can be applied. If this condition is not met, adjusted versions of the tests or non-parametric methods are used. The adjustment of the results in SPSS is performed by the application, but in the case of Jamovi or R / Python languages, it is necessary to perform alternative tests, such as the Welch's test.

Dependent variable	Number of items	Correct answer		Partially correct answer		Incorrect answer	
		No. of students	Percent	No. of students	Percent	No. of students	Percent
Variable 1	Item 1	84	78,5%	21	19,6%	2	1,9%
	Item 2	90	53,9%	12	11,2%	5	4,7%
	Item 3	102	95,3%	0	0	5	4,7%
	Item 4	91	85,1%	0	0	16	14,9%
	Item 5	95	88,8%	12	11,2%	0	0
	Item 6	91	85,1%	14	13,1%	2	1,9%
	Item 7	84	78,5%	16	14,9%	7	6,5%
Variable 2	Item 8	93	86,9%	2	1,9%	12	11,2%
	Item 9	105	98,1%	0	0	2	1,9%

Dependent variable	Number of items	Correct answer		Partially correct answer		Incorrect answer	
		No. of students	Percent	No. of students	Percent	No. of students	Percent
Variable 1	Item 1	29	17,4%	108	64,7%	20	11,9%
	Item 2	81	48,5%	51	30,5%	35	20,9%
	Item 3	94	56,3%	0	0	73	43,7%
	Item 4	88	53,7%	0	0	79	47,3%
	Item 5	114	68,3%	53	31,7%	0	0
	Item 6	68	34,5%	54	32,3%	55	32,8%
	Item 7	41	35,6%	33	19,8%	93	55,7%
Variable 2	Item 8	62	37,1%	54	32,3%	51	30,5%
	Item 9	34	20,4%	0	0	133	79,6%

Figure 3. Example of an error of not respecting the comparison criteria

Comparisons must be made in *compliance with the comparison criteria*, between equivalent and rigorously defined groups. It is not recommended to compare the average of the entire sample with the average of a subgroup or to compare groups from different contexts without methodological justification. A situation identified in the analysed researches refers to the fact that the results of a sample are compared with the results of both researched groups. For example, in Figure 3, the author of the study formulates

conclusions regarding significant increases in the research results by referring to a sample (107 subjects for each item) compared to the total number of subjects (157 subjects for each item), which generates important statistical errors. In addition, the author committed calculation errors (in item 2 the total percentage on the line is not 100), which demonstrates the use of inadequate tools (manual calculations) and negligence in the accuracy of the data.

3. Correlations of variables

The relationships between variables are substantiated by correlation coefficients, or correlation analysis allows the identification and evaluation of the relationships between the investigated variables. In this context, it is well known that the choice of the type of correlation coefficient depends on the characteristics of the variables and the distribution of the data. Thus, the most frequently used methods are [12]:

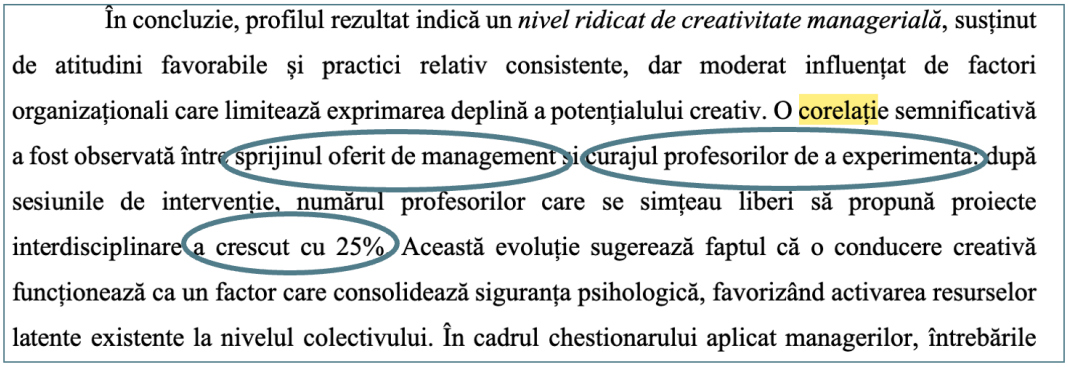
- Pearson coefficient (quantitative variables, normally distributed, linear relationship);
- Spearman coefficient (one ordinal and one quantitative variable, or small sample, or quantitative variables, which are not normally distributed);
- Kendall coefficient (the variables under investigation are both ordinal, or have a small number of values);
- partial correlation (same conditions as in the case of Pearson correlation, but the effects of other collateral variables on those under investigation are eliminated).

On the one hand, incorrect selection of the coefficient can lead to erroneous interpretations, on the other hand, the SPSS / Jamovi software tools allow the calculation of these coefficients, only by checking the appropriate option, which facilitates the commission of an error, because the type of variables investigated is not verified and no execution restrictions are imposed.

At the same time, the correct interpretation of the correlations is also very important, from the perspective of: the direction of the correlation: positive (directly proportional) or negative (inversely proportional); the intensity of the relationship: weak, moderate or strong; and the statistical significance.

The value of the coefficient indicates the strength of the relationship, and the p-value allows the establishment of statistical significance.

Regarding the correlations between the researched variables, it is important that the formulation of conclusions is based on scientific evidence, not on appearances. Only on the basis of the calculated coefficients and the level of significance, the researcher can formulate conclusions regarding the existence or non-existence of relationships between the investigated variables. In the analysis carried out by the authors, research was identified in which reference is made to the correlation between two variables (figure 4), without calculating any correlation coefficient, therefore without scientific substantiation.



În concluzie, profilul rezultat indică un *nivel ridicat de creativitate managerială*, susținut de atitudini favorabile și practici relativ consistente, dar moderat influențat de factori organizaționali care limitează exprimarea deplină a potențialului creativ. O corelație semnificativă a fost observată între sprijinul oferit de management și curajul profesorilor de a experimenta: după sesiunile de intervenție, numărul profesorilor care se simțeau liberi să propună proiecte interdisciplinare a crescut cu 25%. Această evoluție sugerează faptul că o conducere creativă funcționează ca un factor care consolidează siguranța psihologică, favorizând activarea resurselor latente existente la nivelul colectivului. În cadrul chestionarului aplicat managerilor, întrebările

Figure 4. Example of erroneous formulation of conclusions regarding the correlation between the researched variables

However, it is important to note that the existence of a correlation does not necessarily imply a causal relationship.

4. Justification of statistical significances

Traditionally, the conceptual framework of research also includes drawing conclusions regarding the confirmation or rejection of the proposed research hypotheses. These hypotheses are typically concerned with comparing the means of dependent variables in order to determine the statistical significance of differences between group means. In this context, it is essential for the researcher to substantiate the statistical significance of mean differences with scientific evidence, such as the results of statistical tests for comparing means. Hypothesis testing requires the use of appropriate statistical procedures, and the choice of a statistical test depends on several factors, including the number of groups being analysed, the type of variables, the distribution of the data, and whether the samples are independent or dependent.

Thus, *the type of variables* serves as a major criterion in the application of parametric or non-parametric tests. For quantitative variables with normal distribution, parametric tests are used, such as the t-test. For ordinal variables or distributions other than normal, non-parametric tests are applied, such as: Mann–Whitney U, Wilcoxon, Kruskal–Wallis, Friedman, χ^2 tests, etc.

Also, depending on *the number of groups*, one-sample tests, two-independent-sample tests, two-paired-sample tests or multiple-sample tests are used. In this regard, the statistical software suggests through the title of the applied methods the experimental situation in which they can be applied. For example, in the classic case of comparing the means of two independent samples with the quantitative and normally distributed research variable, the test is called "Independent Samples t-Test".

Only after performing the appropriate test, according to the type of variable and the number of groups, does *the interpretation of the results* proceed, which involves the analysis of the corresponding statistical coefficients (t, U, W, Z, χ^2, etc.) and the level of statistical significance (p). Typically, if $p < 0.05$, the differences or relationships identified

are considered statistically significant, and if $p \geq 0.05$, the null hypothesis cannot be rejected.

Only following these steps will allow the researcher to *formulate conclusions* regarding significant or insignificant differences between means and not the unprofessional use of these terms for visual comparisons and subjective assessments. Beginning researchers must understand that a difference in means is significant or not, depending on the volume of research groups, the variance of the researched variable, etc.

Thus, as recommendations for researchers, to strengthen the quality of pedagogical research it is necessary:

1. Scientific argumentation of all interpretations and conclusions through appropriate statistical criteria and indicators.
2. Presentation of processed data in the annexes of the papers, in compliance with the rules on the protection of personal data.
3. Presentation to scientific centres (departments, doctoral schools, editorial offices of scientific journals) of the databases used, when possible, for verification and reproduction of the results.
4. Development of statistical and digital skills of researchers.
5. Use of specialized software to reduce calculation and interpretation errors.

Conclusions

Statistical argumentation is one of the fundamental conditions of contemporary pedagogical research. The quality of the results depends on the rigor of the data collection process and data processing, the appropriate choice of statistical tests and the correct interpretation of the results obtained.

The faithful completion of databases, the correct comparison of groups, the analysis of relationships between variables and the verification of statistical significance contribute to increasing the validity and credibility of the research. In this context, the development of a culture of research based on statistical evidence becomes an essential condition for the progress of educational sciences and for the substantiation of modern educational decisions.

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