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Use of Digital Technology in Teaching. Analysis of Results Using Basic Descriptive Statistics and Categorical Principal Components

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Abstract A descriptive-quantitative study was conducted to compare two methods of analysis. A quantitative-descriptive research was carried out on the perception of digital technology as a support tool in teaching. A standardized questionnaire was applied to identify the following dimensions of technology use: frequency, benefits, infrastructure, and perception of institutional policies. The analysis was carried out with arithmetic means and with categorical principal component analysis (PCA). The results in both methods indicate that teachers who conduct research use digital technology the most, while experimental teachers use it the least. The PCA method is more robust and allows to obtain the reliability of the results obtained, its use is recommended on the basic statistical analysis to increase the validity of the results.

Keywords: *education research, digital technology, principal component analysis*

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1. Introduction

In descriptive research, subjective value judgements are generally made about different attributes that are to be measured, and these attributes are recorded in complex variables that are commonly presented as ordered categorical data [1]. Likert's scales are widely used to record subjective value judgments, they are one-dimensional scales that have only one dimension on which they symmetrically measure the degree of agreement or disagreement [2]. The spacing between responses is symmetric, since they offer the same number of positive and negative options [3], so these values generate an ordered categorical variable.

PCA is used in research that includes a limited sample and has many dimensions and variables, which are generally highly correlated. PCA is a variable reduction technique, which decreases the dimensionality of the space and eliminates the correlation that may exist between the variables by transforming them into uncorrelated orthogonal variables [4].

There is controversy about how to conduct the analysis of ordered categorical variable, Stevens was the first to establish the paradigm that this type of data can only be analyzed by non-parametric techniques, these do not need to make hypotheses about parameters and are limited to analyzing the nominal or ordinal properties of the data [5,6], other researchers supported this scheme of analysis as the only valid one [7], the other researchers, however, are in favor of the use of parametric statistics that require normal behavior of the data [8]. But specifically, are parameters and statistics such as means and standard deviations significant in the context of ordinal data? These are important concerns because it is the scale used to measure results in different studies that developed for example in medicine, psychology, and education [9].

Despite the controversy surrounding this paradigm, is common to use basic descriptive statistics (BDE) for the analysis of Likert scales, however, parametric analysis of Likert scale variables is suggested only as a pilot analysis [10]. In addition, BDE analysis of ordinal categorical variables allows limited descriptive analysis because the scale is always preserved in such analysis. Quantitative variables, such as age, must be transformed into categorical variables during the analysis to evaluate them.

Multivariate analysis is used as a statistical technique to reduce and interpretation variables. This method allows us to and interpret data that result from having more than one variable on a sample of individuals, which are highly correlated, that is, they are not independent [11].

PCA is one of the techniques for reducing, this technique is used to reduce many variables, in other so-called principal components, the components are unrelated, so that a few explain most of the variance of the observed phenomenon [12].

The statistical procedure used to reduce categories is the optimal scaling, which is based on the assignment of numerical quantifications to the categories of each variable. They allow for the analysis of categorical data in models with too few observations, or too many variables, retaining, if required, the hierarchical level of ordinal variables [13].

This method of optimal scaling of categorical variables used in the interpretation of the answers to a questionnaire-survey, carried out in a study at the Autonomous Metropolitan University, Faculty Azcapotzalco (UAM-A), on the perception of the use of digital technologies as a support to teaching in chemistry classes and research. These results were compared with those obtained through BDE to determine which method offers a better interpretation of the results.

2. Methodology

Descriptive study that measures the perception of the use of digital technology (DT) as a support in teaching and research. A standardized questionnaire using the Likert scale was applied to describe four dimensions of teachers' perception of the use, conception, and beliefs in relation to digital technology [14] in their teaching practice and research work (Table 1).

Table 1. Likert scale used to measure perception

Ordinal category	Numerical value
Nothing / Strongly disagree	1
Little / Disagree	2
Regular / Okay	3
Acceptable / Accepted in agreement	4
Very acceptable / Completely agree	5

A sample of 30 teacher-researchers was selected for convenience, of which 10 teach theory, 10 teach experiments and 10 teachers who also do research. The standardized questionnaire collected 10 variables on the benefits of the use of digital technological tools (DTT); 23 on frequency, 9 variables measuring infrastructure and 6 on the perception of policies to support the use of technologies at UAM-A, Table 2.

Table 2. Analysis axes and questions for each axis

Dimension	Item	Questions
General information about the teacher	1-6	1. Year you joined UAM-A 2. Bachelor's degree 3. Academic degree 4. chemistry course that he teaches. 5. (only one) 6. Age 7. Gender
Digital technology tools (DTT) usage frequency	7-14	8. Uses DTT in its teaching practice. 9. How much do you use the following DTT? 10. If your classroom has technological means, do you use them? 11. The UAM-A offers courses for teachers to learn how to use DTT. 12. Attend workshops and courses virtually to update. 13. Using DTT requires investing more time in class preparation. 14. Using DTT, such as social networks and platforms implies more dedication from the teacher to review the student's work. 15. Using DTTs involves extra expense. To answer the questions in this axis, five answer options were established: a) none, b) little, c) regular d) acceptable and e) a lot.
Benefits to use	15-16	16. Using DTT brings benefits to teaching. 17. The DTTs of the UAM-A have contributed to improve the teaching of their classes. To answer the questions in this axis, five answer options were established: a) strongly disagree, b) disagree, c) neither agree nor disagree, d) agree and, e) strongly agree.
Technological infrastructure	17-25	18. Do you have a computer at home? 19. Do you have internet at home? 20. Do you have a personal computer in your cubicle? 21. Do you have internet in your cubicle? 22. It is convenient to invest in technological infrastructure. 23. It is important to have a computer in your cubicle. 24. The classroom has the technological conditions for a digital class. 25. The institution provides you with the support to use DTT technologies. 26. The technological infrastructure is sufficient for full-time teachers. To answer the questions in this axis, five answer options were established: a) none, b) little, c) regular d) acceptable and e) a lot.
Policy Perception	26-31	27. It is important to use technologies or DTT in teaching and learning. 28. Technology generates changes in the way of teaching. 29. I have the necessary knowledge to use DTTs in my teaching practice. 30. It is important to invest in training of the DTTs oriented to human resources. 31. There is diffusion in the use of DTT in teaching and learning. 32. We have personnel trained in the use of DTTs and who support the teaching staff. To answer the questions in this axis, five answer options were established: a) none, b) little, c) regular d) acceptable and e) a lot.

2.1. Analysis of Data

The dimensions of analysis were frequency of use DTT, benefits to use, perception about the existing infrastructure and knowledge about policies to encourage the use of DT in the institution.

These dimensions were analyzed in three areas: teachers who carry out research, theoretical teachers, and experimental teachers. The correlations between the variables of each dimension were obtained to evaluate the viability of the analysis by means of main components, which aims to reduce these variables in a smaller number of components that contain the maximum variance that explains the phenomenon. The frequency of the Likert scale categories was obtained for each variable in all areas of analysis.

Data were evaluated with PCA when an effective correlation between variables by dimensions was verified, through optimal scaling of categorical variables, at the ordinal scaling level to respect the hierarchy of the data. Two main components were calculated for each dimension and the variances for each were obtained. The values for each transformed variable were graphed to observe the consistency of the scaling and the scaling graphs by category were obtained for each variable. Finally, the perceptual map was obtained which describes the differences in perceptions in the different areas (observation units) of analysis (teacher-researcher, theoretical teacher, and experimental teacher) for each dimension of analysis (frequency, benefits, infrastructure, and institutional policies).

The optimal scaling model of the variables was evaluated by Cronbach's Alpha, which establishes the reliability of the USEDTT questionnaire used to measure perception in the use of digital technology, in de Table 3 shown the values of Cronbach's Alpha [15].

Table 3. Values Cronbach's Alpha

Axis of analysis	Cronbach's Alpha	Reliability
Frequency	0.973	Acceptable
Benefits	0.973	Acceptable
Infrastructure	0.967	Acceptable
Policies	0.951	Acceptable

The results of the PCA were compared with the results of the application of BDE (arithmetic mean of each variable and for each dimension). The PCA was performed with IBM SPSS Statics software, version 22.

3. Results

Table 4 below shows the characteristics of the sample under study and the scaled values for each dimension in the first component obtained from the categorical principal component analysis.

A total of 61.22 % of the total number of full-time research professors teaching chemistry courses (49) at UAM-A participated. Of the total number of teachers who participated, 60% were women and 40% men. 57% of teachers have a doctorate degree, 33 % have a master's degree and only 10% have only a bachelor's degree. The ages of teachers range from 39 to 77, with an average age of 60.

Table 4. Characteristics of chemistry teachers and scaled values

T	G	Gd	A	F	B	I	P
R	M	D	73	0.47	0.74	0.45	0.36
R	M	D	46	0.58	-0.05	0.44	0.54
R	F	M	60	0.52	0.25	0.45	0.39
R	M	D	77	0.84	0.36	0.45	0.53
R	F	M	61	1.27	0.83	0.45	0.81
R	F	D	37	0.48	0.93	0.45	0.72
R	F	D	64	1.65	0.94	0.45	0.81
R	F	D	62	0.27	0.79	0.45	0.69
R	F	D	60	1.29	0.76	0.45	0.78
R	F	D	73	0.93	0.83	0.43	0.73
TT	F	D	57	0.04	-0.43	0.18	-0.15
TT	F	D	66	-0.40	-0.16	-0.39	0.46
TT	F	L	64	-1.56	-3.49	-3.49	-3.55
TT	F	D	47	0.26	0.13	0.42	0.58
TT	M	M	65	0.58	0.14	0.44	0.30
TT	F	D	49	-0.34	-0.70	0.38	0.54
TT	M	D	39	-0.40	0.21	0.37	0.33
TT	F	D	49	-0.87	-0.39	0.14	0.23
TT	M	M	64	1.44	0.77	0.44	0.67
TT	F	M	61	0.02	0.31	0.20	-0.11
ET	M	M	67	-1.72	-0.29	-1.06	-0.61
ET	M	M	70	-1.50	-0.97	0.19	-0.43
ET	F	M	71	1.22	0.81	0.11	0.49
ET	F	D	67	-1.52	-0.50	0.32	-0.39
ET	M	L	65	-1.67	-0.55	0.32	-1.27
ET	F	L	64	-1.62	-2.83	-3.58	-2.80
ET	M	D	73	-1.01	0.43	-0.43	-1.59
ET	M	M	64	1.18	0.77	0.34	0.40
ET	F	M	46	0.31	0.71	0.33	0.35
ET	F	D	49	-0.88	-0.07	0.32	-0.34

T: Type, G: Gender, Gd: Grade, A: Age, F: Frequency, B: Benefits, I: Infrastructure, P: Policies. R: research teacher, TT: theoretical teacher; ET: experimental teacher. D: Doctorate, M: Master's; L: Degree, M: male; F: female.

The variables that evaluate the dimensions (frequency, benefits, infrastructure, and perception of the policy) were high correlated (0.5≥R≤0.9). Figure 1 shows the results of the teachers' perception of the use of the DT. It shows the arithmetic average of the values of the first component of the PCA analysis by dimension.

Figure 2 shows the same results as Figure 1, but in this case, BDE were used, showing the results as an average of the arithmetic average, for each of the variables that measure the use of DT.

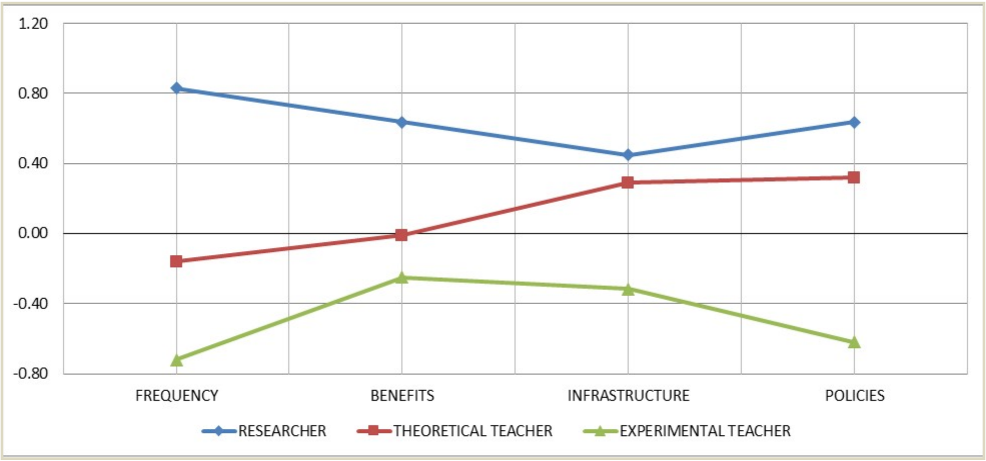

Figure 1. Perception of DT (PCA analysis)

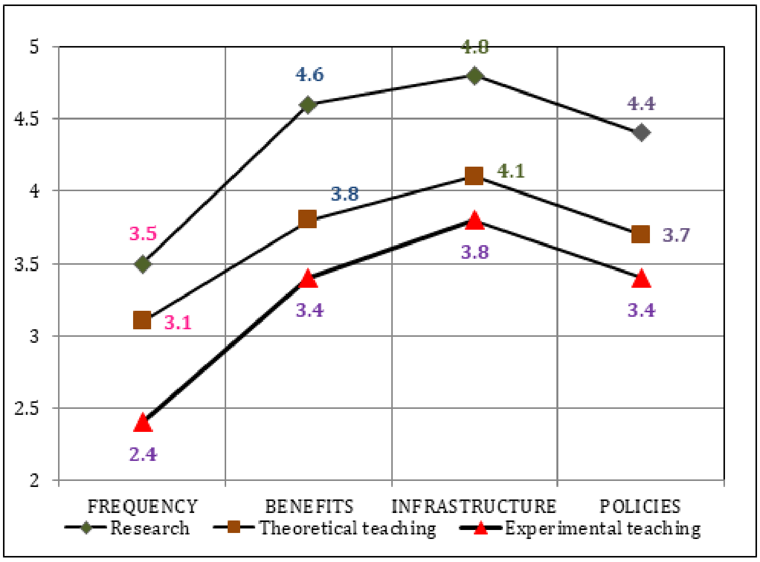

Figure 2. Perception of DT (BDE analysis)

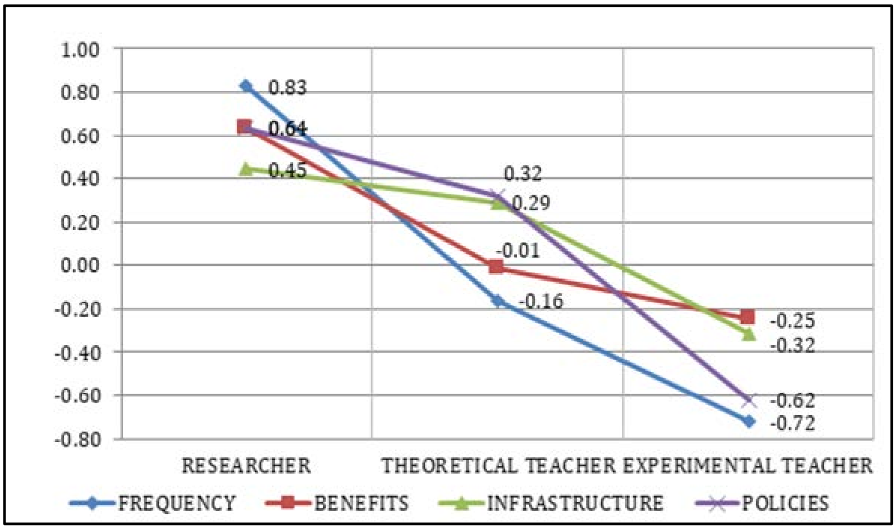

Figure 3. Perception of DT use by scope of analysis (PCA analysis)

Figure 3 shows the perception in the use of DT by field of analysis: researcher, theoretical teacher, and experimental teacher. Arithmetic average of PCA is shown.

Figure 4 shows the perception in the use of DT by field of analysis: Researcher, theoretical teacher and experimental teacher using basic statistics (arithmetical averages) of the Likert scale.

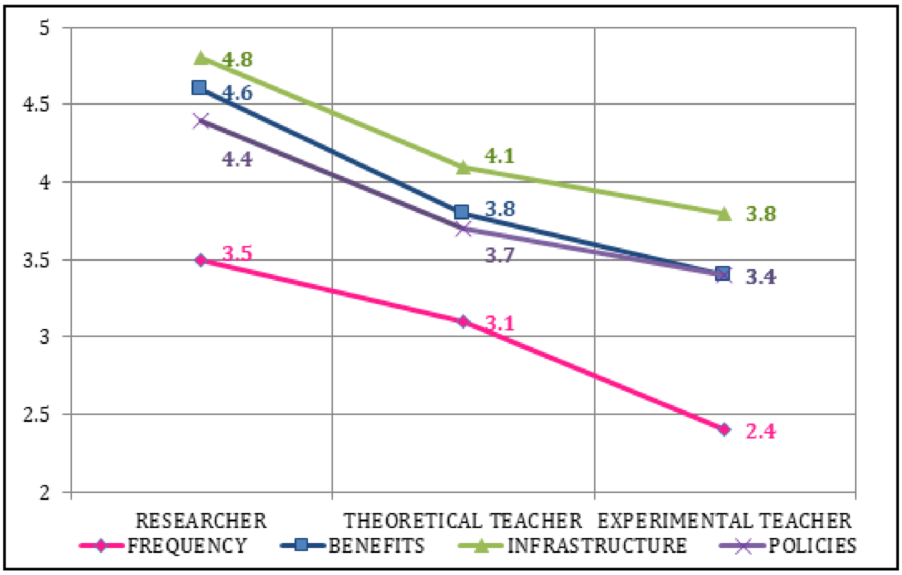

Figure 4. Perception of DT use, analysis using BDE

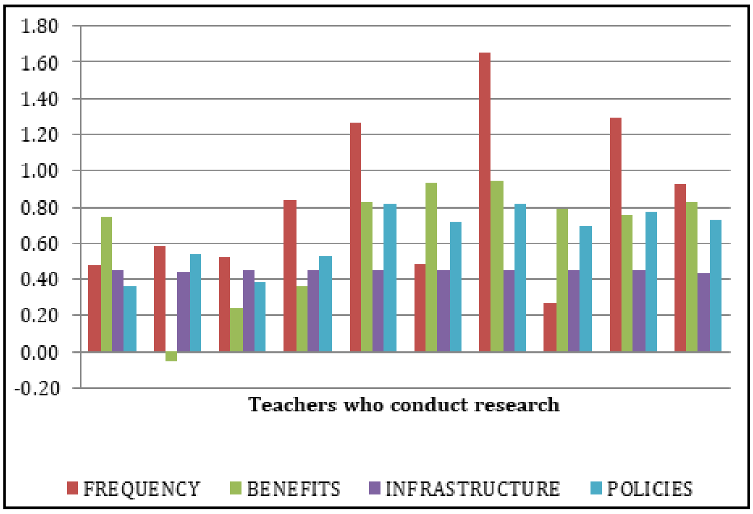

Figure 5. Perception of DT use by teachers conducting research (PCA analysis)

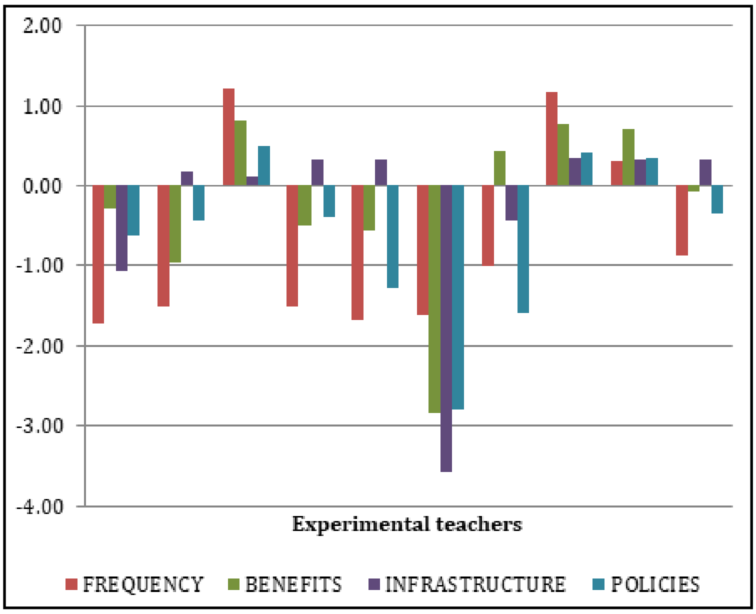

Figure 6. Perception of DTT use by teachers conducting experimental teaching (PCA analysis)

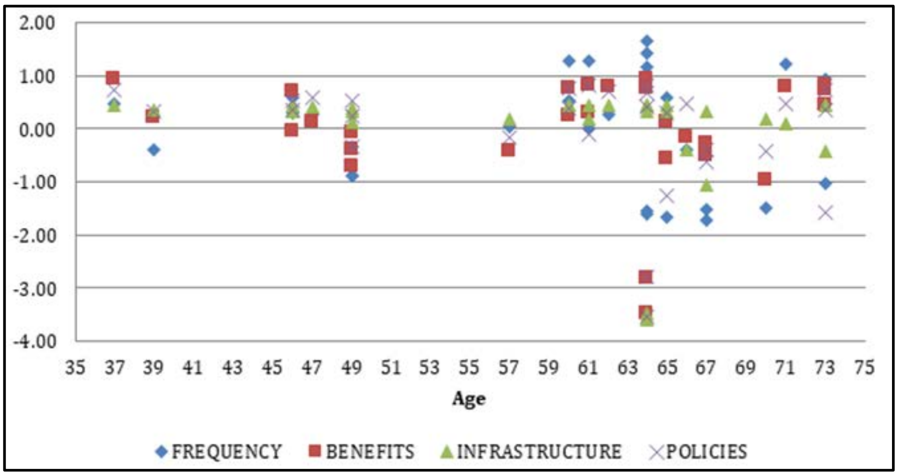

Figure 7. Teachers' perception of DT use by age (PCA analysis)

Figure 5 and Figure 6 show the perception in the use of digital technologies, by teachers conducting research (10 teachers) and by teachers conducting experimental teaching (10 teachers teaching chemistry laboratories) respectively.

Figure 7 presents the results of the use of digital technology by age of the teacher. This graph shows that not all teachers aged 60 and over have a negative perception of the use of technology.

4. Discussion

Examination of the results shows the following differences in the use of the different methods of analysis, in the case of the infrastructure dimension, theoretical teachers and research teachers have a smaller difference in perception when doing the PCA than when doing it with BDE. In the case of the policy perception dimension, theoretical teachers and research teachers show a more approximate perception in the PCA than when doing it using arithmetic mean averages. However, note the change in concavity of the curve of the research professors and theoretical professors in the PCA with respect to the BDE method, Figure 1, and Figure 2, which shows the change obtained in the results of the dimensions in the different areas when applying the PCA method.

In Figure 3, and Figure 4, the same results are shown again by both methods of analysis, although a similar trend is shown, there are more marked differences for some variables such as policy perception, between the different types of teachers. The Figure 5 shows that although theoretical teachers have a better perception of the use of DT than experimental teachers, but they also make less use of these technologies and perceive negative benefits in their use as do experimental teachers, although to a lesser extent. In the case of the experimental teachers, there is one that does not perceive any utility in the use of DT, but there are at least three teachers that if they have a positive perception about the use of these technologies. In the Figure 7 it can be observed that teachers with more than 60 years old, also have a positive perception in the use of the technologies and that there are some teachers that despite being less than 50 years old, have a negative perception about the use of these technologies.

Regarding the advantages and disadvantages in the application between the use of BDE and the PCA method, the following concepts will be referred to: basic descriptive statistics is a method of data analysis with various statistics (arithmetic mean, mode and, median among others) and PCA is also a descriptive technique, which uses an algorithm applied to data or complex variables of a population [16] through statistical software due to the complexity of the calculations.

PCA is commonly used to perform a descriptive analysis of data, although there are some related inferential techniques, its use is less common. The PCA seeks the projection according to which the data are best represented in terms of least squares, in one or two dimensions that allow interpretation of the data with greater ease of which has a very large number of variables. A disadvantage of this method is that it is little used in practice, because it requires knowledge of statistical concepts such as eigenvectors, principal components, eigenvalues, covariance matrix, correlation matrix, etc. The Table 5 shows the advantages and disadvantages of the BDE versus the PCA method.

Table 5. Advantages and disadvantages between BDE and PCA

Advantages BDE	Advantages PCA
- Easy to apply on a number of samples with a small value. - Simple mathematical calculation - No high costs - No training in statistical software required - Relatively easy to interpret	- Convenient when you have a large sample number with several variables. - Multivariate data screening. - Grouping of observation units. - Reduction of variables that explain the highest percentage of variance of the original data.
Disadvantages BDE	**Disadvantages PCA**
- It is not recommended to apply in large populations because it is very time consuming. - The method with extreme values and open intervals is affected.	- A computer and software are required due to the complexity of the mathematical calculation. - Knowledge of advanced statistics.

In this research, the PCA method, as well as the analysis with the BDE, indicated that between the units of observation, which were called study areas in this research (research teachers, theoretical teachers and experimental teachers) the results are equivalent and it can be said without a doubt that researchers have a higher (positive) perception of the use of Digital Technology than theory teachers and much higher than the perception of experimental teachers, in the Figure 8 it is shown by arrows (direction) that there was no significant change between both methods according to our results.

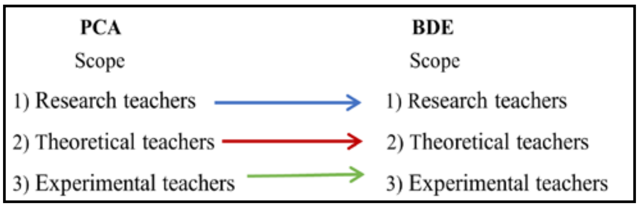

Figure 8. Comparison of the acceptance of DT use between BDE and the PCA method

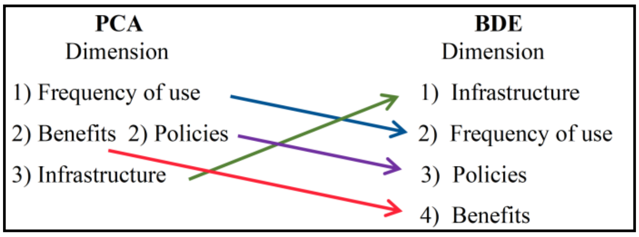

Figure 9. Comparative classification of the dimensions in the field of research, between BDE and the PCA method

Of the dimensions analyzed (use, benefits, infrastructure, and frequency) the order of perception changes between both methods as shown in Figure 9, Figure 10 and Figure 11, considering that position 1 is the one with the best perception and that the arrows indicate the change in importance between the dimensions between the methods. Figure 9 shows the differences in the change of importance of the dimensions studied in the scope of the research.

Figure 10 shows the differences in change of importance of the dimensions studied in the field of theoretical teaching.

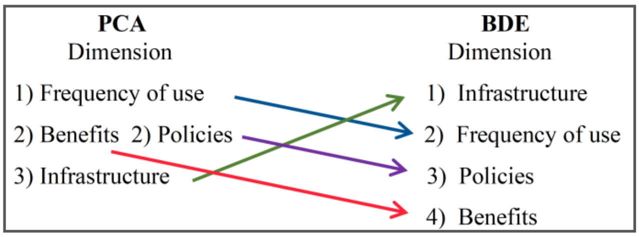

Figure 10. Comparative classification of the dimensions in the field of theoretical teaching, between BDE and the PCA method

Figure 11 shows the differences in change of importance of the dimensions studied in the field of Experimental Teaching between the analysis methods.

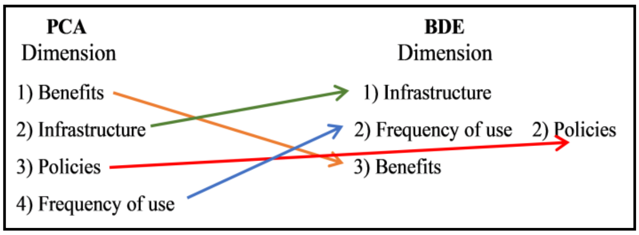

Figure 11. Comparative classification of the dimensions in the field of experimental teaching, between BDE and the PCA method

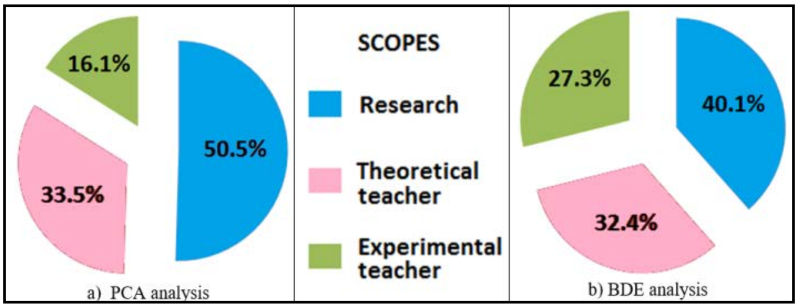

Figure 12. Percentage of acceptance of DT in each of the areas: research, theoretical, and experimental teaching

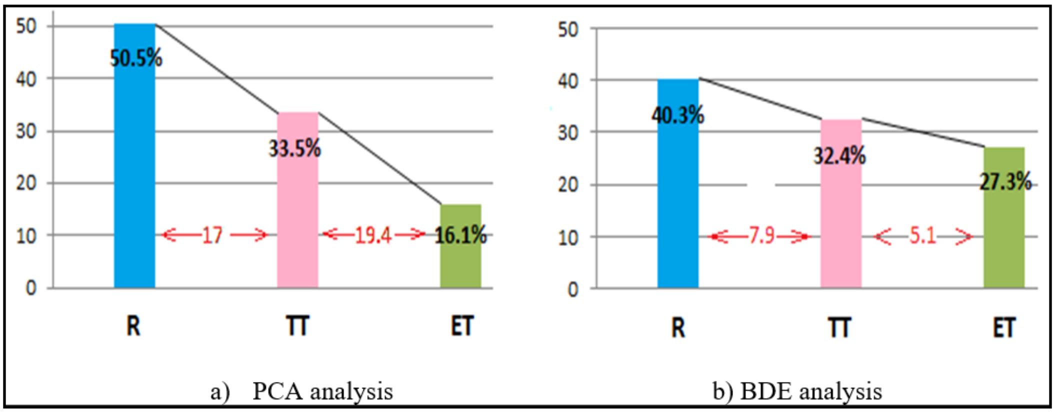

Figure 13. Acceptance of DT between domains (research (R), theoretical (TT) and experimental teaching (ET)), the slope of the line joining the domains is steeper in the PCA analysis.

Figure 12 shows the acceptance of DT in each of the three areas of study, finding that the PCA technique, Figure 12a, is more subtle in presenting the difference in acceptance than the BDE technique, Figure 12b.

According to the percentages in the PCA it is observed that researchers use, understand, and believe in the support of DT in their practice 3 times more than laboratory teachers, and 1.5 times more than theory teachers, while the analysis with the BDE researchers use, understand, and have a better perception of the usefulness of DT by 1.5 times more than laboratory teachers and 1.2 times more than theory teachers.

In Figure 13, the difference in slopes is shown and the score differences between the areas have been calculated, with the largest difference in Figure 13a, which corresponds to the PCA method. The percentage difference between areas in both statistical techniques is shown in red.

From this analysis, we infer that the PCA methodology is more subtle in showing differences in the perception of teacher DT than the BDE statistical methodology, and that the PCA analysis is much more robust and can be evaluated by Cronbach's alpha.

5. Conclusions

The two methods of analysis used to collect teachers' perceptions in the use of digital DT technologies are equally used in various researches, however, the method of scaling categorical variables to generate PCA is a more robust method of statistical analysis compared to basic statistics, which allows to reduce the number of variables in a study in one or two dimensions for analysis and interpretation, and also requires a number of initial conditions for its use, such as that the variables are dependent on each other, that the units of observation have a similar variance, that the variables are measured on the same scale, so that a linear combination of them (components) will explain most of the variance of the data and it is a technique in which the reliability of the results obtained can be known (through the Cronbach's alpha value), whereas basic statistics does not allow the use of any statistic to evaluate the results.

With the same data set, in this research the BDE analysis was equivalent to the PCA analysis in terms of perception by field of study (research, theory and experimental), allowing for more discrimination in the scopes and between them, as shown in this comparative analysis. Both methods show the same qualitative trend in the perception of the use of digital technology by field but the PCA shows changes in importance by dimensions in each of the areas of the data. Given that the PCA method is more robust and allows the reliability of the results obtained to be obtained, its use is recommended over the BDE analysis, to increase the validity of the conclusions.

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References

[1] Svensson, E. Ordinal invariant measures for individual and group changes in ordered categorical data. Statistics in medicine, 17 (24), 2923-2936. Dec.1998.

[2] Likert, R. A technique for the measurement of attitudes. *Archives of psychology*. 1932.

[3] Burns, A. and Burns, R. Basic marketing research 2th (Ed.). New Jersey: Pearson Ed. 2008.

[4] Jackson, J. E. A user's guide to principal components (Vol. 587). John Wiley & Sons. 2005.

[5] Murray, J. Likert data: what to use, parametric or non-parametric? *International Journal of Business and Social Science*, *4*(11). Sep.2013.

[6] Stevens, S. S. On the theory of scales of measurement. *Science*, New Series, 103(2684), 677-680. Jun.1946.

[7] Jamieson, S. Likert scales: How to (ab) use them? *Medical education*, *38*(12), 1217-1218. Dec.2004.

[8] Norman, G. Likert scales, levels of measurement and the “laws” of statistics. *Advances in health sciences education*, *15*(5), 625-632. Feb.2010.

[9] Perdices, M. Some Thoughts about the Suitability of the Reliable Change Index (RCI) for Analysis of Ordinal Scale Data. *Brain Impairment*, *15*(3). Dec.2014.

[10] Allen, I. E., & Seaman, C. A. Likert scales and data analyses. *Quality progress*, *40*(7), 64-65. Juy.2007.

[11] Cuadras Avellana, C. M. Nuevos métodos de análisis multivariante. Barcelona: CMC Editions; 2012.

[12] Jolliffe, I. T. Choosing a subset of principal components or variables. *Principal component analysis*, 111-149. 2002. [E-book] Available: Springer Series in Statistics. Springer, New York, NY.

[13] Navarro Céspedes, J. M., Casas Cardoso, G. M., & González Rodríguez, E. Principal Component and Regression Analysis for Categorical Data. Application to Arterial Hypertension. *Revista de Matemática: Teoría y Aplicaciones 17(2).* Juy.2010.

[14] Díaz, M. C., Rosillo, V. M. L., & de León, O. G. P. Percepción de los docentes de la utilización de las Tecnologías de la Información y la Comunicación. *Revista Iberoamericana de Educación*, (53/6). Sep-2010 [Online] Available: https://rieoei.org/historico/deloslectores/3375Castillo.pdf].

[15] Fernández-Sánchez, L., & Loreto-Gómez, C. E. Validation of an instrument to measure the perception of teacher-researchers in the use of digital technology. *Avances en Ciencias e Ingeniería*, 11 (4), 157-169. Oct/Dec.2020. [online] Avaliable: https://www.executivebs.org/publishing.cl/aci/2020/Vol11/Nro4/10-ACI1368-20-full.pdf.

[16] Karamizadeh, S. Abdullah, S. Manaf, A. Zamani M. & A. Hooman, A. An Overview of Principal Component Analysis, *Journal of Signal and Information Processing*, 4 (3B), 173-175. Aug.2013.