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Accesibilidad estadística en artículos publicados en revistas científicas de educación (Europa-Latinoamérica) incluidas en Scimago Journal Ranking

Statistical accessibility in articles published in scientific education journals (Europe-Latin America) included in Scimago Journal Ranking

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Palabras clave

Accesibilidad Estadística, Artículos Científicos, Educación, Métodos Estadísticos.

Resumen: Accesibilidad Estadística es la capacidad que posee un lector de interpretar correctamente los análisis estadísticos que se efectúan en documentos investigativos. El objetivo general de este estudio es evaluar la accesibilidad estadística en artículos científicos de educación publicados en revistas de Europa y Latinoamérica incluidas en *Scimago Journal Ranking* durante el periodo 2016-2020. Se desarrolló una investigación empírica, cuantitativa, relacional, con fines bibliométricos con base en un diseño *ex post facto,* con una muestra de 1617 artículos originales extraídos de 10 revistas científicas de España, Brasil y México. Alrededor de 39.5% (n=639) de los artículos emplea procedimientos estadísticos de nivel intermedio de complejidad, especialmente pruebas no paramétricas y tablas de contingencia, le siguen las pruebas t y la correlación de Pearson. Los procedimientos más complejos (superiores a regresión lineal simple) se registraron en 31.5% (n=609) de los documentos. La mayor accesibilidad se relacionó con la producción en coautoría y con publicaciones realizadas en España, mientras que en Latinoamérica la accesibilidad es menor. El registro de artículos en educación matemática es menor en comparación con otras áreas. El uso de estadística va ganando terreno dentro de la investigación en educación, aunque el nivel de complejidad de los procedimientos es medio. En educación matemática parece haber predilección por medios especializados siendo relevante profundizar el estudio de la accesibilidad en esta área. Se discute el papel de la calidad editorial de las revistas en relación con el nivel de accesibilidad mayor para aquellas editadas en Europa

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Keywords

Statistical Accessibility, Scientific Articles, Education, Statistical Methods.

Abstract: Statistical Accessibility is the ability of a reader to correctly interpret the statistical analyzes that are carried out in investigative documents. The general objective of this study is to evaluate the statistical accessibility of scientific educational articles published in Europe and Latin America journals included in the Scimago Journal Ranking during the period 2016-2020. An empirical, quantitative, relational research was developed for bibliometric purposes based on an ex post facto design, with a sample of 1617 original articles extracted from 10 scientific journals from Spain, Brazil, and Mexico. Around 39.5% (n=639) of the articles use statistical procedures of intermediate level of complexity, especially non-parametric tests, and contingency tables, followed T test and Pearson's correlation. The most complex procedures (superior to simple linear regression) were recorded in 31.5% (n=609) of the documents. The greater accessibility was related to co-authored production and publications made in Spain, while in Latin America accessibility is lower. The registration of articles in mathematics education is lower compared to other areas. The use of statistics is gaining ground within educational research, although the level of complexity of the procedures is medium. In mathematics education there seems to be a predilection for specialized media, and it is relevant to deepen the study of accessibility in this area. The role of the editorial quality of the journals in relation to the level of greater accessibility for those published in Europe is discussed.

Introduction

Usefulness of statistics in scientific research

Statistics is of great importance in mathematics education as it helps to understand multiple concepts and procedures to strengthen random thinking, it also provides modern society with tools for the analysis of scientific phenomena that help to resolve doubts about research, social and economic issues (Del Pino & Estrella, 2012; Ponteville, 2014).

The use of this science in research is supported by rigorous processes related to the collection of information and the structure of a database, to be subsequently analyzed through procedures that serve the researcher to test their hypotheses, which affects decision-making regarding the evidence obtained (Flores-Ruiz, Miranda-Novales & Villasís-Keever, 2017; Navarro, Chuhuaicura, Soto-Faúndez & Soto, 2019).

The articulation between methodological aspects and the use of statistics is a primary task in scientific research (Escalona & Gómez, 2012; McPherson, 2013), insofar as the appropriate use of statistical methods in accordance with what was proposed in the planning of a research guarantees access to clear results and concise conclusions (Massip, Soler & Torres, 2012; Praena, 2015). The correct choice of statistical tests is crucial in research, which involves recognizing the study objective, the characteristics of the sample, the type and number of measures of the variables analyzed, and the overall complexity of the research design (Ritz, Kniss & Streibig, 2014; Flores-Ruiz et al., 2017). Here the concept of statistical accessibility comes into play (De Granda et al., 2002), as it defines the level of knowledge of an individual to understand and appropriately interpret the tests used in data analysis (Massip et al., 2012).

The focus of the study on the use of statistics and its level of accessibility is based on the importance of this area for education in general and for scientific research in particular. For many years, specialized authors have been pointing out that the correct application of statistics guarantees reliable results and success in an investigation, which is why it is necessary to have trained statistical advisors who provide better quality in scientific studies (Hurtado, 2017). They have also reviewed that statistics has

transcended the academic context being of great value both for research and university education as well as for everyday life processes (Gil, 2003).

Considering the above, scientific publications currently employ a large number of data analysis procedures, and the use of statistics has become popular among researchers. Thus, it is feasible to point out that the complexity of statistical techniques has been increasing, which also demands higher levels of statistical knowledge from readers. The literature differentiates at least three levels of knowledge required to understand the use of statistics in a publication: the first level corresponds to readers with appropriation of descriptive statistics, the second level includes readers with knowledge of some inferential procedures, and the third level groups readers with a high degree of interpretation and statistical analysis (Carré, Jiménez, Martín & Carrenca, 1996). This is directly related to the concept of statistical accessibility, which classifies by levels the complexity of the analysis procedures used, which demand a greater or lesser level of mastery of statistical reasoning.

Statistical accessibility

The original idea of statistical accessibility is found in Emerson and Colditz (1983), who focused on studies published in scientific journals of biomedical sciences. According to them, it was quite common for researchers to identify the basics of the best-known tests such as Chi-square and Student's t-tests, but knowledge of other tests of greater complexity was inferior, and some authors were even likely to be unaware of them. Given the task of characterizing the statistical procedures used in scientific publications, Emerson and Colditz (1983) created a table of statistics organized into four categories, the first and broadest of which, although not named by the authors, involves most of the statistical analyses. The second category welcomes "multiple comparisons" methods, i.e., any method that involves adjustment of p-value significance levels when several statistical comparisons are made; an example of these are cost-benefit analysis methods. The third category described by Emerson and Colditz (1983) is called "Power" and includes the use of statistical power methods to determine sample sizes and the probability of accepting the null hypothesis when it is false. The authors also include within this category post hoc analyses focused on statistical power.

Finally, the last category is named by the authors as "Other", which includes specialized models, many adjusted or created by researchers in their scientific processes, and also includes innovative procedures to date such as discriminant analysis and its use in complex research procedures.

Subsequently, the original classification was translated and adapted to Spanish (Mora, Ascaso and Vilalta, 1995; 1996), making some adjustments in its categories to comply with the analysis of statistical procedures that were a trend in medical journals (González de Dios and Moya, 1996; González de Dios, 2002). Finally, Díaz Mujica (2007) revised the proposed categories, adjusting them to updated procedures, thus achieving a better organization of the statistical tests (Table I).

Table I. Statistical categories proposed by Díaz Mujica, modified from other authors.

N°	Category	Description
0.	No statistics	No application of statistical analysis of data.
1.	Descriptive statistics only	Percentages, means, standard deviations, histograms.
2.	Student's t-test	For one or two samples (paired and/or independent data), parametric tests.
3.	Bivariable tables	x2 test, Fisher's exact test, McNemar's test, Kappa.
4.	Non-parametric tests	Sign test, Mann-Whitney U test, Wilcoxon T test, Friedman test, Ranking test.
5.	Demo-epidemiological statistics	Relative risk, odds ratio, log odds, measures of association, sensitivity and specificity.
6.	Pearson's linear correlation	Classical product-moment correlation (r).
7.	Simple regression	Least squares regression with one independent variable and one dependent variable.
8.	Variance analysis	Analysis of variance and covariance, F-tests, Analysis of Variance (ANOVA), Scheffe, Levene.
9.	Transformation of variables	Use of transformations (e.g. Logarithmic).
10.	Non-parametric correlation	Sperman's Rho, Kendall's Tau, trend tests.
11.	Multiple regression	Including polynomial regression and stepwise regression.
12.	Multiple comparisons	Tests to handle multiple interferences on the same data: Bonferroni, Scheffé, Duncan, Newman Keuls tests.
13.	Adjustment and standardization	Standardization of incidence and prevalence rates.
14.	Multivariate tables	Mantel-Haenszel procedure, log-linear models.
15.	Power and sample size	Determination of sample size as a function of a detectable (or useful) difference, post hoc analysis.
16.	Survival analysis	Actuarial life tables, Kaplan-Meier survival estimation, survival regression (logistic and Cox regression) and others (Breslow extension, Kruskall-Wallis, long rank test, proportional hazard models).
17.	Cost-benefit analysis	Estimation of costs to compare alternative guidelines (cost-effectiveness).
18.	Latent class analysis	Structural equation models aimed at contrasting theories.
18	Other miscellaneous analyses	Sensitivity analysis, in outbreaks, discriminant, mathematical models.
19.	Multivariate analysis	It includes several techniques: typology, discriminant analysis, factor analysis, correspondence analysis, etc.
20.	Reliability analysis	Alpha Cronbach's test, Structural Equation Models aimed at testing instruments, etc.

Source: taken from Díaz Mujica (2007), adapted from González de Dios (2002), adapted from Mora (1995, 1996), adapted from Emerson and Colditz (1983).

According to the type of procedure applied, the level of statistical accessibility is defined. This is a simple process, although González de Dios and Moya (1996) recognize that it is a relatively arbitrary procedure, it has been widely accepted in research on the subject. In a general sense, three levels of accessibility to differentiate are recognized (Díaz Mujica, 2007; González de Dios & Moya, 1996): Accessibility <2, refers to studies in which no statistics were used or this only reaches the level of descriptive analysis; Accessibility >7 are studies with statistical analysis of greater complexity than simple regression, i.e., complex methods and multivariate analysis.

Clearly, procedures that go beyond the descriptive and go as far as simple regression constitute the category of intermediate complexity or accessibility. This means that simple linear regression analysis constitutes a kind of threshold between bivariate statistical procedures, accessible to any reader who has passed a basic level of training in statistics (as is the case with the training offered in undergraduate courses), and procedures of a higher level of complexity.

Statistical accessibility aims to quantitatively weight the knowledge about statistics that a reader should possess, for the correct interpretation of the data analysis included in a publication (Chiapella, Lazzarini and Montenegro, 2019). Several works have applied accessibility evaluation responding to varied objectives and analysis approaches, although it is in the area of biomedical sciences where this body of knowledge has been mostly exploited. Romani, Márquez and Wong (2010), for example, evaluated the use and frequency of statistical methods in Peruvian biomedical journals, determining that the type of analysis used depends on the subject of the journal; thus, epidemiological statistics are most frequently used in public health and epidemiology, and, as expected, these types of statistics were mostly used in cross-sectional observational studies. Moreno and Martín (2017)

analyzed a series of publications in the field of nursing, identifying a predominance of a basic statistical level, which reflects the use of commonly known statistical techniques and, therefore, little complexity in data analysis.

In educational sciences, it is very difficult to find bibliographic antecedents that apply the analysis of statistical methods to research considering the concept of statistical accessibility, even more so in the specific field of mathematics education, which is why it constitutes a scenario of analysis in which there is much to be done. The study of statistical accessibility can help to identify the level of complexity of data analysis procedures, in addition to informing about the level of readiness expected in readers to access educational scientific content based on the application of quantitative methods.

As a discipline applied to research, for statisticians and researchers who use statistics in their analysis processes (regardless of their training), it is of great value to recognize the stochastic analysis procedures favored in indexed publications, as a way of contributing to the study of the penetration of statistics in research conducted in the educational sciences.

From this scenario, this study outlined as a general objective to evaluate the statistical accessibility in scientific articles in education published in journals included in Scimago Journal Ranking during the period 2016-2020. This objective was broken down into two specific objectives: 1) to identify the main statistical procedures used by defining their level of accessibility, and 2) to evaluate whether accessibility is related to the characteristics of the productions analyzed such as the subject area (mathematics-other), the region where they are published (Spain-Latin America) and the type of signature (co-authorship or single author).

Materials and Method

Design

An empirical, quantitative and relational type of research was developed, which allows starting from the description of the study variables to subsequently test relationships between them without manipulation of the variables. Since this is a bibliometric study, it corresponds to an ex post facto design.

Unit of analysis

The sample of this study is represented by 1617 scientific articles extracted from 10 journals included in the Scimago Journal Report (SJR) as of December 2020. Journals classified in the area of Social Sciences and in the category of Education were selected, opting for the top five Latin American and the top five European journals according to their 2019 SJR index in force at the time. The result in the Latin American context was one journal from Brazil and three from Mexico, while in the European case all were from Spain.

In each of them, all their issues and volumes published between January 2016 and December 2020 were reviewed to select the original articles discarding editorials, letters to the editor, reviews, obituaries and other non-citable publications. The list of journals with their SJR index and the number of articles consulted in each appears in Table II. In total, 47.1% (n=762) of the articles were from Latin American journals and 52.9% (n=855) from the European context.

Table II. Scientific journals selected for the study.

Magazine	SJR	Cuartil (Q)	Index h	Country	Articles
Int. Journal of Educational Tech. in Higher Education a	1.066	Q1	22	España	53
Journal of Psychodidactics	.837	Q1	24	España	90
Journal of Educational Research	.777	Q1	13	España	151
Education XX1	.631	Q2	15	España	139
Journal of Education	.562	Q2	24	España	159
Complutense Journal of Education	.528	Q2	11	España	264
Mexican Journal of Educational Research	.419	Q2	9	México	168
Cadernos de Pesquisa	.406	Q2	14	Brasil	220
Educational Profiles	.397	Q2	9	México	161
Electronic Journal of Educational Research	.372	Q2	11	México	213

Source: SJR Scimago, 2020.

Instruments

For data collection, a data matrix was used in Excel© workbooks, which was subsequently exported to the Statistical Package for the Social Sciences (SPSS) version 25 software for statistical analysis. The purpose of this matrix was to collect data on the characteristics of the articles and the statistical procedures used. Information such as the year of publication, the region of the journal, collaboration in the articles (intra-institutional, inter-institutional, international) was recorded, and all the statistical techniques described by Díaz Mujica (2007) to evaluate the level of statistical accessibility were included. To this list, the Factorial Analysis technique (exploratory and confirmatory) and Decision Tree and/or regression were added as part of the accessibility level >7.

Procedure

Initially, all the articles published in the 10 journals were downloaded and organized by volume, number and year in consecutive order. The articles from the Latin American journals were downloaded first, followed by those from Spain, and then each document was reviewed to record the variables. Special care was taken to review the methodological section and the results in order to clearly identify the statistical procedures applied.

The data were treated with univariate procedures to obtain descriptive information on the statistical tests used in the articles. The characteristics of these contributions were also analyzed descriptively, such as the type of firm, the number of products per region (Spain or Latin America), the type of collaboration and the thematic area.

Subsequently, the relationship between these characteristics and the level of statistical accessibility was tested by applying Pearson's Chi-square (x2) and testing the effect size with the w index (small=.10, medium=.30, large=.50) using the G*Power version 3.1.9.7 program. The identification of the punctual association of the categories was performed with the Corrected Typed Residuals analysis.

Results and analysis

The report of all the statistical procedures identified in the analyzed production has been described in Table III. As can be seen, a little more than one third of the production does not apply quantitative data analysis, while in the case of the articles that do use statistics, these are mostly descriptive. About 39.5% (n=639) of the articles use statistical procedures of intermediate level of complexity, the most common being nonparametric tests and contingency tables, followed in order by the t-test family and Pearson product-moment correlation. Less frequent is the application of simple linear regression, a procedure that serves as a boundary between intermediate statistics and those of greater complexity.

Table III. List of descriptive procedures identified in the evaluated scientific articles

Level	Statistical procedure	f	%
	None	609	37.7
Basic	Descriptive statistics	364	22.5
Intermediate	Student's t-test	144	8.9
	Bivariate tables (contingency)	161	10.0
	Non-parametric tests	163	10.1
	Demo-epidemiological statistics	4	0.2
	Pearson's linear correlation	121	7.5
	Simple regression	46	2.8
Advanced	Analysis of variance (ANOVA and post hoc tests)	188	11.6
	Transformation of variables	2	0.1
	Non-parametric correlation (Spearman's Rho, Kendall's Tau)	53	3.3
	Multiple regression	48	3.0
	Multiple comparisons (Bonferroni, Scheffé, Duncan, Newman Keuls)	39	2.4
	Exploratory or confirmatory factor analysis	112	6.9
	Multivariate tables	35	2.2
	Power, sample size and effect size	126	7.8
	Survival analysis	3	0.2
	Latent class analysis (structural equations)	29	1.8
	Multivariate analysis	125	7.7
	Reliability analysis	298	18.4
	Decision tree (and/or regression)	5	0.3

In the case of advanced procedures, reliability analyses stand out, followed by analysis of variance (ANOVA) with their respective post hoc tests; in third place are tests focused on power, sample size and effect size, as well as multivariate analyses with a similar frequency. The fourth most common advanced procedure was factor analysis.

After assessing the complexity of these statistics, it was identified that 37.7% (n=609) presented a level of accessibility lower than 2, while 30.8% (n=499) of the documents presented accessibility between 2 and 7, and finally, articles with accessibility higher than 7 amounted to 31.5% (n=609).

In addition, the characteristics of the articles were evaluated, such as the subject area, the region where they are published and the type of signature, variables whose association with the level of accessibility was tested. With regard to the subject area, only 4.1% (n=67) of the articles were identified as being in mathematics education, which is a very small number and therefore it was not possible to calculate the relationship with the level of accessibility. This result reveals that scientific publication in mathematics appears to be in specialized journals, with very few contributions in general journals.

On the other hand, co-authored publication prevailed with 1335 articles (82.6%) with cooperation between authors, of which 45.9% (n=742) was intra-institutional, 28% (n=452) was inter-institutional and only 8.7% (n=141) was international. The association analysis showed a statistically significant relationship between the type of signature (single author, with co-authorship) and accessibility ($x2[2]=101.197$, $p=.000<.001$, $w=.30$, $1-\beta=1.0$), which was of higher level (>7) in multi-author publications (CTR=8.2). In turn, the highest statistical complexity was recorded in publications published in Spain (CTR=18.3), while accessibility levels <2 (CTR=9.6) and 2 to 7 (CTR=8.4) were related to contributions published in Latin American journals ($x2[2]=335.94$, $p=.000<.001$, $w=.61$, $1-\beta=1.0$).

Conclusions

The results obtained in this study have made it possible to identify, in the first instance, that most of the works published in article format employ some statistical procedure. Thus, 67.3% (n=1008) of the works studied apply quantitative data analysis while only a little more than a third resort to qualitative approaches or are productions that do not require data analysis, as is the case with academic essays or reviews.

These results support the argument that statistics has become an instrument of great importance for the educational sciences, being used in scientific research in different educational areas as a valuable tool that provides precision in the reasoning and inferences obtained from evidence. In this sense, the results reinforce the idea of Gil (2003), who assumes as improper the conceptions that disdain the use of statistics to approach educational phenomena; instead, the author highlights the contributions of statistical science to the whole research process by considering it more than a simple tool for data analysis. Similarly, the results described demonstrate that researchers in the educational sciences find in statistics a useful method to enrich their research processes, as argued by Flores-Ruiz et al. (2017) and Navarro et al. (2019), statistics provide essential elements for decision-making in the face of the hypotheses formulated, which allows researchers to assume informed decisions duly supported by empirical evidence.

About 39.5% of the products analyzed in this study use statistical procedures with a medium level of complexity according to the classification of Díaz Mujica (2005), since the most used methods included nonparametric tests and the use of contingency tables. As is evident, these procedures require the use of descriptive measures as a previous analysis; therefore, these results coincide with the reports offered in different fields of knowledge, such as the epidemiological and hygiene data provided by Massip et al. (2012), who also report a high percentage of use of descriptive statistics and nonparametric tests based on double-entry tables such as Pearson's Chi-square. For their part, Fernández, Miñaña, Guzmán and Hita (2003), when analyzing production in the medical field of urology, indicate that descriptive procedures appear in 39.3% of the literature consulted and the use of bivariate tables in about 12.1%.

The data from this study indicate that intermediate accessibility is identified in 30.8% of the articles and high accessibility (greater than 7) in 31.5% of them, information that suggests, as in the studies described (Fernandez et al., 2003; Massip et al., 2012), that, in a general sense, researchers' mastery of statistical tests is at medium levels of depth. Previously Chiapella et al. (2019) have stated that the evidence on the degree of complexity of statistical procedures in scientific production does not imply that the reader is a great connoisseur of sophisticated data analysis tests, this by virtue of the fact that, even in medical journals where statistics is the common element of information analysis, the most commonly treated tests are usually employed. Following this logic, readers of scientific information in educational sciences require a medium level of statistical skills that allow them to access reasoning based on some inferential processes (Carré et al., 1996), while the high level of interpretation and data analysis is limited to less than one third of the production published in the journals included in this study.

However, to this discussion must be added the role played by the region in which the journals studied are published, insofar as the data obtained show a statistically significant relationship of high accessibility with the journals published in Spain, while those from the Latin American scenario show a relationship with medium and low accessibility. Among the journals in the sample, it is precisely those from Spain that have the highest SJR indicator, which implies the most important evaluation within the system proposed by Elsevier based on the counting of citations received as a criterion of journal impact. Additionally, as Diestro, Ruiz and Galán (2017) point out, Ibero-American journals show a notorious lag in terms of impact and editorial quality compared to those from Anglo-Saxon countries, but even between journals from Latin America and Spain these differences are found. Many of the journals from Hispanic and Lusophone America that are included in the SJR, also respond to editorial criteria defined by classification systems such as REDALYC and LATINDEX, which have

limitations such as seeking criteria that unify journals discounting their identity particularities for the former (Rozemblum, Unzurrunzaga, Banzato and Pucacco, 2015), or that emphasize formal aspects as happens with the latter (Diestro et al., 2017).

On the other hand, in Spain, since 2006, the editorial evaluation initiative of the Spanish Foundation for Science and Technology called FECYT Quality Seal has been applied, which, in addition to addressing formal aspects, emphasizes relevant criteria such as the quality of dissemination, the ability to attract the public, the level of scientific quality in the contents, the visibility and audience it has and its level of impact (Hernández Pina and Maquilón, 2010). In Spain, the prestige of the journal is measured, to a large extent, by its obtaining this seal and, within the sample analyzed, the six journals have it. Thus, editorial impact evaluation criteria focused on the quality of the scientific contributions of the contents may influence the use of sophisticated methods that offer contributions to the topics of study from the methodological point of view and from the novelty of the results, thanks to the analytical procedures used. This could explain the difference in the level of accessibility of Spanish journals compared to those published in Latin America. In this regard, Fernández et al. (2003) point out that the level of complexity of the articles in national journals is less demanding, while in foreign journals the demand is greater, which gives more importance and recognition to the study, in addition to reaching an international readership that is more advanced in statistical knowledge.

Finally, a result of special interest in the field of research in mathematics education is the small number of articles in the area identified in the journals studied. In total there were 67 disciplinary studies among the total of 1617 documents, a result that suggests that researchers in the area opt for the submission and publication of studies in journals with a specialized focus, instead of betting on journals with a general focus that publish various topics of the educational sciences. This coincides with what was described by Adamuz-Povedano, Jiménez-Fanjul and Maz-Machado (2013), who showed that in mathematics and education (and in other areas such as psychology) it is difficult to find scientific articles in non-specialized journals. It is feasible that researchers prefer specialized journals in order for their studies to be known by colleagues who are experts in the subject; similarly, the particularity of mathematical topics may not be appealing for general focus journals, which forces editorial specialization.

As limitations of this work, it is important to mention firstly the choice of the source of indexing of the journals, since only articles from journals included in the SJR were taken, which reduces the scope in terms of coverage of educational production and causes the number of journals published on European soil to be greater. The second limitation is associated with the need to identify the correct statistical technique, since many articles do not accurately describe these procedures, which requires that the information be uploaded by experts in the subject domain and that the methods and results of the articles be carefully read. Finally, other variables such as methodological design, type of research, research cutoffs and other aspects of the methodological structure could be included as variables for analysis in future work in order to analyze whether accessibility varies according to these properties.

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