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Articulo Original

Technology Integration in the Teaching-Learning Process of Biostatistics in Medical Students

Integración de tecnología en el proceso de enseñanza-aprendizaje de bioestadística en estudiantes de medicina

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Abstract

The integration of Information and Communication Technologies (ICT) into the teaching of quantitative subjects represents one of the most significant challenges facing contemporary medical education. The aim of this study was to determine the use of ICT in the teaching and learning of biostatistics among sixth-semester medical students at a public university in Ecuador. A quantitative-descriptive methodology was adopted, involving the administration of structured and validated questionnaires to 41 students and 3 lecturers. The instruments explored five dimensions: access to digital resources, frequency of use by lecturers, pedagogical perception, openness to methodological change, and lecturers' digital competence. The results reveal that 73% of teaching staff do not routinely use technological tools, whilst 61% of students lack digital resources specialised in biostatistics. In contrast, 84% of students expressed a favourable attitude towards the use of educational software, and 90,2% perceive that ICT would substantially improve their understanding of the subject matter. These figures highlight a marked gap between students' readiness for change and current pedagogical and infrastructural conditions. It is concluded that the systematic implementation of ICT in the teaching of biostatistics urgently requires coordinated institutional strategies for teacher training, the design of interactive resources and the improvement of technological infrastructure, as necessary conditions for strengthening essential statistical competencies in evidence-based medical practice.

Keywords: *Biostatistics, Information and Communication Technologies, Medical Education, Digital Competencies, University Teaching.*

Resumen

La integración de las Tecnologías de la Información y Comunicación (TIC) en la enseñanza de asignaturas cuantitativas representa uno de los retos más significativos para la educación médica contemporánea. El presente estudio tuvo como objetivo determinar el uso de TIC en el proceso de enseñanza-aprendizaje de bioestadística en estudiantes del sexto semestre de Medicina de una universidad pública ecuatoriana. Se adoptó una metodología cuantitativa-descriptiva, con la aplicación de encuestas estructuradas y validadas a 41 estudiantes y 3 docentes. Los instrumentos exploraron cinco dimensiones: acceso a recursos digitales, frecuencia de uso docente, percepción pedagógica, disposición al cambio metodológico y competencia digital docente. Los resultados revelan que el 73% del profesorado no emplea habitualmente herramientas tecnológicas, mientras el 61% del estudiantado carece de recursos digitales especializados en bioestadística. En contraposición, el 84% de los estudiantes manifestó actitud favorable hacia el uso de software educativo, y el 90,2% percibe que las TIC mejorarían sustancialmente su comprensión de los contenidos. Estas cifras evidencian una pronunciada brecha entre la disposición estudiantil al cambio y las condiciones pedagógicas e infraestructurales actuales. Se concluye que la implementación sistemática de TIC en la enseñanza de bioestadística requiere, de forma impostergable, estrategias institucionales articuladas de capacitación docente, diseño de recursos interactivos y mejora de infraestructura tecnológica, como condiciones necesarias para el fortalecimiento de competencias estadísticas esenciales en la práctica médica basada en evidencia.

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Palabras clave: *Bioestadística, Tecnologías de la Información y Comunicación, Educación Médica, Competencias Digitales, Enseñanza Universitaria.*

1. Introduction

The rapid advancement of Information and Communication Technologies (ICT) has substantially transformed educational processes at a global level, redefining the roles of teacher and student, as well as the dynamics of knowledge construction. In the university context, the integration of digital tools constitutes not only a pedagogical trend, but a strategic necessity to ensure the relevance and quality of professional training (Unesco, 2023). This transformation is particularly relevant in disciplines of high conceptual and mathematical complexity, such as biostatistics, a fundamental subject in the training of medical students and health sciences professionals.

Biostatistics provides the methodological foundations for the interpretation of clinical and epidemiological data, the critical appraisal of scientific literature, and evidence-based decision-making (Sánchez et al., 2021). However, it has historically been perceived by medical students as one of the most abstract and difficult subjects, with failure rates above average in numerous Latin American universities (Ávila & Freire, 2019). This situation demands a thorough review of the pedagogical approaches employed in its teaching.

Within this framework, ICT emerges as tools with significant pedagogical potential. Their incorporation into learning environments promotes interactivity, autonomous learning, and the practical application of content, overcoming the limitations of the traditional expository model (Cabero-Almenara, 2014). As noted by Area-Moreira et al. (2018), well-implemented educational technology not only revitalises the teaching process, but also generates more inclusive, flexible, and adaptive learning environments suited to the individual needs of students.

At the international level, evidence of the benefits of ICT in the teaching of exact and statistical sciences is robust. Studies conducted in Europe, Asia, and North America document significant improvements in motivation, academic performance, and learning retention when statistical software, interactive platforms, and multimedia resources are used in the classroom (Llorente-Cejudo & Cabero-Almenara, 2021; Redecker, 2020). In particular, the use of tools such as SPSS, R, Stata, and online statistical simulators has been shown to facilitate the understanding of abstract concepts by enabling the direct visualisation and manipulation of data (Báez, 2013; Da Costa Silva, 2013).

In the Latin American context, and specifically in Ecuador, the reality is notably different. Despite advances and classroom implementation, the effective incorporation of ICT in university teaching of quantitative subjects remains limited and heterogeneous (Secretaría de Educación Superior, Ciencia, Tecnología e Innovación [SENESCYT], 2018). Prior research has identified persistent gaps in teacher digital competence, the availability of specialised resources, and the design of technology-mediated teaching strategies in Ecuadorian universities (Montolio, 2011; Universidad Técnica Particular de Loja [UTPL], 2014). This issue is particularly pronounced in regional universities, where technological resources are limited and teacher training in digital competencies has not been addressed systematically. Biostatistics teaching in these institutions is predominantly conducted under the expository model, with limited use of computational tools and without teaching materials adapted to the local context. This scenario generates significant conceptual gaps that compromise the quality of learning and, ultimately, the analytical competence of future health professionals (Berwick et al., 2018).

In light of this context, the present study aimed to determine the use and application of ICT in the teaching-learning process of biostatistics amongst sixth-semester students of the Medical degree at a public Ecuadorian university. The study seeks to generate empirical evidence to underpin pedagogical and institutional decision-making oriented towards the systematic and effective integration of technology in the teaching of this critical subject.

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2. Theoretical Framework

2.1. ICT in Contemporary University Education

The integration of ICT in higher education has been conceptualised from multiple theoretical perspectives. From Ausubel's (2002) theory of meaningful learning, digital tools facilitate the connection between the student's prior knowledge and new content, by enabling visual representation, direct data manipulation, and immediate feedback. This substantial, non-arbitrary connection between knowledge is precisely what characterises deep and lasting learning.

For his part, Vygotsky's constructivist approach contributes the concept of the zone of proximal development, suggesting that ICT can act as mediation tools that expand the learner's cognitive capacities beyond what they could achieve autonomously (Area-Moreira et al., 2018). In this sense, collaborative platforms, statistical simulators, and adaptive learning environments constitute technological mediators that enhance the development of complex competencies such as statistical reasoning and critical thinking.

From a more instrumental perspective, the European Framework for the Digital Competence of Educators (DigCompEdu) proposed by Redecker (2020) describes six areas of digital competence that educators must develop to effectively integrate ICT into their practice: professional engagement, digital resources, digital pedagogy, assessment, empowering learners, and facilitating learners' digital competence. This framework represents a valuable reference for the design of teacher training programmes in the university context.

2.2. Biostatistics and Evidence-Based Medical Education

Biostatistics occupies a central place in the medical curriculum, given its role as the methodological foundation of evidence-based medicine (EBM). According to Berwick et al. (2018), the ability of physicians to interpret statistics from clinical studies, evaluate relative risk, analyse survival curves, and understand concepts such as statistical significance and confidence intervals, constitutes an essential clinical competency in contemporary professional practice.

However, traditional biostatistics teaching in medicine has prioritised the memorisation of formulae over conceptual understanding and practical application. This decontextualised approach hinders the transfer of statistical knowledge to the clinical context and generates mathematical anxiety that is associated with low academic performance (Sánchez et al., 2021). Recent studies demonstrate that the use of interactive statistical software and real clinical cases in biostatistics teaching significantly reduces this anxiety and improves students' statistical self-efficacy (Llorente-Cejudo & Cabero-Almenara, 2021).

2.3. Barriers to ICT Integration in Latin American Universities

The specialised literature identifies three main categories of barriers to ICT integration in Latin American higher education: first-order barriers, related to external factors such as infrastructure, access to resources, and institutional policies; and second-order barriers, linked to internal teacher factors such as attitudes, pedagogical beliefs, and level of digital competence (Cabero-Almenara, 2014).

In the Ecuadorian case, SENESCYT (2018) identified that, despite the expansion of technological infrastructure in public universities during the period 2013–2018, the gap in teachers' digital competencies continued to be the main obstacle to effective pedagogical integration. This finding is consistent with the results of regional research indicating that the mere availability of technology does not guarantee its effective pedagogical use, unless accompanied by continuous teacher training and clear institutional support policies (Báez, 2013; Salinas, 2020).

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3. Methodology

3.1. Research Design

This research adopted a quantitative approach with a descriptive cross-sectional design. This design enabled the systematic description of the characteristics, perceptions, and behaviours of educational actors in relation to ICT use in biostatistics teaching, at a specific point in the academic cycle (Hernández-Sampieri et al., 2014). The study does not establish causal relationships, but does provide solid descriptive evidence to underpin proposals for pedagogical intervention.

3.2. Participants

The study population comprised all students enrolled in biostatistics in the sixth semester of the Medical degree at a public Ecuadorian university (N = 41) and the three lecturers responsible for the subject during that period. Given the small size of the population, all available subjects were included, constituting a population census. Participation was voluntary and data confidentiality was guaranteed through informed consent. The sociodemographic characteristics of participants are presented in Table 1.

Table 1

Sociodemographic Characteristics of Study Participants

Characteristic	n	%	Media (DE)	Rango
Students (n = 41)				
Age (years)	41	100	22,4 (1.8)	19 – 28
Sexo femenino	24	58,5	—	—
Sexo masculino	17	41,5	—	—
Acceso a dispositivo propio	34	82,9	—	—
Lecturers (n = 3)				
Years of teaching experience	3	100	11,3 (4.5)	7 – 16
Formal ICT training	1	33,3	—	—
Uso habitual de TIC en clase	0	00,0	—	—

Note. *Age and years of experience data are expressed as mean ± standard deviation. SD = standard deviation. ICT = Information and Communication Technologies.*

3.3. Instrument and Data Collection

Two structured ad hoc questionnaires were designed: one directed at students (27 items) and one at teaching staff (18 items), both organised into five dimensions. Items employed five-point Likert scales (1 = strongly disagree to 5 = strongly agree) and multiple-choice questions. The content of the instruments was validated through expert judgement (n = 5 specialists in university education and applied statistics) and Cronbach's Alpha coefficient was calculated to verify internal consistency (α = 0,87 para el cuestionario estudiantil; α = 0,82 para el docente), valores que superan el umbral mínimo recomendado de 0,70 (Nunnally & Bernstein, 1994). Las dimensiones e indicadores del instrumento se presentan en la Tabla 2.

Table 2

Structure of the Data Collection Instrument by Dimension

Dimension	Main Indicators	Ítems	Respondents
D1 – ICT Access and Availability	Available digital resources, device type, connectivity	6	Students
D2 – Teacher ICT Use and Frequency	Frequency of classroom use, tools employed, perceived barriers	5	Docentes
D3 – Pedagogical Perception	Perceived software usefulness, impact on comprehension, motivation	7	Both

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D4 – Readiness for Methodological Change	Attitude towards innovation, willingness to adopt ICT, digital self-efficacy	5	Students
D5 – Teacher Digital Competence	Level of tool proficiency, training needs	4	Docentes

Note. *D = Dimension. Questionnaires were administered in person during regular academic hours, with an average duration of 20 minutes.*

3.4. Data Analysis

The collected data were processed using IBM SPSS Statistics version 26,0 statistical software. A univariate descriptive analysis was conducted, calculating absolute and relative frequencies for categorical variables, and means with standard deviations for continuous variables. Results are presented in frequency tables and bar charts constructed according to scientific visualisation criteria. The level of significance established for all analyses was $p < 0,05$.

3.5. Ethical Considerations

The study was approved by the institution's Research Ethics Committee and was authorised by the relevant academic authorities. All participants signed an informed consent form guaranteeing the voluntary nature of their participation, the confidentiality of their responses, and the exclusive use of data for scientific purposes. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki (WMA, 2013) and current national regulations on university research.

4. Results

The results of the quantitative analysis reveal consistent patterns across three central axes: ICT use by teaching staff, student access to digital resources, and readiness for methodological change. Table 3 presents a comprehensive summary of the main indicators obtained.

Table 3

Main Indicators of Use, Access, and Readiness Towards ICT in Biostatistics Teaching

Indicator	n	%	Interpretation
STUDENTS (n = 41)			
Lacks specific digital resources for biostatistics	25	61,0	High gap in access to specialised materials
Uses only search engines and general internet	22	53,7	Absence of specialised tools
Favourable attitude towards educational software	34	84,0	Strong readiness for methodological change
Considers that ICT would improve their understanding	37	90,2	Very high perception of pedagogical usefulness
Has previously used SPSS or statistical software	9	22,0	Low level of prior exposure to statistical software
LECTURERS (n = 3)			
Does not regularly use ICT in class	2	66,7	Predominance of traditional methods
Uses ICT sporadically	1	33,3	Occasional use without systematic integration
Recognises need for digital training	3	100,0	Unanimous demand for continuing training
Identifies institutional barriers to ICT use	3	100,0	Insufficient infrastructure and policies

Nota. *Percentages were calculated on the total number of participants per group (n = 41 students; n = 3 lecturers). Data correspond to affirmative or agreement responses for each indicator.*

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4.1. Limited ICT Use by Teaching Staff

A significant majority of teaching staff (n = 2; 66,7%) declared that they do not regularly use technological tools in biostatistics teaching, relying exclusively on traditional methodologies centred on lecture-based instruction and manual exercise solving. Only one lecturer (33,3%) reported incorporating digital resources sporadically, primarily slide-based presentations, without integration of statistical software or interactive platforms. No lecturer (0%) indicated habitual and integrated ICT use in their pedagogical practice. Figure 1 illustrates the distribution of ICT use frequency amongst teaching staff.

Table 4

Frequency of ICT Use in Biostatistics Teaching Practice (n = 3)

Category of Teacher Use	Relative Frequency (%)	%
Does not regularly use ICT		73%
Sporadic / occasional use		27%
Regular and integrated use		1%

Note. *Values represent the percentage of lecturers in each use category. The horizontal scale indicates the relative frequency (%).*

This pattern reflects a significant methodological lag compared to current higher education teaching standards, and is consistent with prior research documenting resistance to change in traditional university environments (Cabero-Almenara, 2014; Báez, 2013). Lecturers identified the main reasons for this lag as: lack of formal training in digital tools (100%), insufficient institutional infrastructure (100%), and limited time for designing digital materials (66,7%).

4.2. Limited Access to Digital Resources by Students

Some 61% of students (n = 25) reported having no specific digital resources for biostatistics learning, relying solely on general web search engines (53.7%) and videos on platforms such as YouTube (37%). The use of statistical software was reported by only 22% of students (n = 9), and most attributed this to prior experiences in other subjects rather than its use in biostatistics. Institutional educational platforms (such as Moodle) were used by only 19% of students to access subject-specific materials. Figure 2 presents the distribution of digital resource sources used by students.

Table 5

Digital Resource Sources Used by Students for Biostatistics Learning (n = 41)

Digital Resource Source	Percentage of students (%)	%
Without specific biostatistics resources		61%
Search engines and general internet		54%
Videos and tutorials (YouTube, etc.)		37%
Statistical software (SPSS, R, Excel)		22%
Institutional platforms (Moodle)		19%

Note. *Multiple-choice response; percentages do not sum to 100%. Data reflect use reported by students outside class hours.*

These findings reveal a critical shortage of specialised teaching materials adapted to the local context, which limits deep assimilation of statistical content and encourages surface learning based on academically unvalidated sources.

4.3. High Student Readiness Towards ICT Use

In contrast to the described limitations, students demonstrated a markedly positive attitude towards the incorporation of technology in the learning process. Some 84% (n = 34) expressed interest in using specific educational software for biostatistics, 90,2% (n = 37) perceived that ICT would substantially improve their understanding of course content, and 88% (n = 36) expressed willingness to learn new

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digital tools. Additionally, 78% (n = 32) preferred active methodologies over lecture-based instruction. Figure 3 summarises the dimensions of student attitude towards ICT.

Table 6

Student Attitude Towards ICT Use in Biostatistics Learning by Dimension (n = 41)

Dimension **de actitud estudiantil**	**Percentage of favourable response (%)**	%
Interest in biostatistics educational software		84%
Perception of improved understanding with ICT		90%
Willingness to learn digital tools		88%
Preference for active vs. lecture-based methodologies		78%
Perceived digital self-efficacy (medium-high level)		63%

Note. *Values represent the percentage of favourable responses (agree or strongly agree on the 5-point Likert scale) for each dimension assessed.*

This result demonstrates high student receptiveness to methodological change, constituting a key facilitator for the implementation of pedagogical innovations. Table 4 systematises the main barriers identified for ICT integration, according to teachers' perceptions.

Table 7

Barriers Identified for ICT Integration in Biostatistics Teaching (Teacher Perception, n = 3)

Identified Barrier	**Docentes**	**%**	**Impact Level**
Lack of teacher ICT training	3/3	100,0	Critical barrier (High)
Insufficient technological infrastructure	3/3	100,0	Critical barrier (High)
Shortage of licensed statistical software	2/3	66,7	Moderate-high barrier
Lack of specialised digital teaching resources	2/3	66,7	Moderate-high barrier
Lack of time for digital materials design	2/3	66,7	Moderate-high barrier
Resistance to methodological change	1/3	33,3	Moderate barrier
Insufficient institutional support policies	3/3	100,0	Critical barrier (High)

Note. *Impact levels were defined based on the frequency of barrier identification: High = identified by 3/3 lecturers; Moderate-High = identified by 2/3; Moderate = identified by 1/3.*

5. Discussion

The findings of this study confirm and expand upon prior evidence regarding the gap between the pedagogical potential of ICT and its effective incorporation into university biostatistics teaching in Latin American contexts. The identified pattern characterised by high student readiness, limited teacher use, and restricted access to specialised resources aligns with what Cabero-Almenara (2014) terms the paradox of technological integration, in which subjective conditions favour change whilst structural ones obstruct it.

The percentage of teachers who do not regularly use ICT (66.7%) is consistent with prior research in the Ecuadorian and Latin American context. Báez (2023) & Hidalgo et al. (2024) documented, in their studies on curricular ICT integration in Spanish-speaking universities, that the traditional teaching model centred on unidirectional knowledge transmission continues to predominate even in institutions with good technological infrastructure. The underlying cause, identified convergently in the literature, is not lack of access to technology, but rather the absence of pedagogical training that would enable its strategic integration into instructional design.

This interpretation aligns with Redecker's (2020) DigCompEdu framework, which establishes that teacher digital competence transcends instrumental knowledge of tools to encompass the capacity to select, adapt, and evaluate them according to specific learning objectives. In this sense, the results of the present study underscore the urgency of designing continuing professional development programmes that develop not only technical skills, but integrated pedagogical-digital competencies.

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The high student readiness towards ICT (84% – 90%) is consistent with the profiles of current university student generations, who display greater familiarity with digital environments and more interactive learning expectations (Area-Moreira et al., 2018; Salinas, 2020). This finding is particularly relevant for biostatistics teaching, a subject that historically generates high levels of mathematical anxiety among medical students (Sánchez et al., 2021). The positive disposition reported suggests that the introduction of interactive educational software such as statistical simulators, probability distribution applets, or analytical environments using R or SPSS could be received favourably and generate the motivational and cognitive effects documented in the international literature (Llorente-Cejudo & Cabero-Almenara, 2021).

From the perspective of meaningful learning (Ausubel, 2002), the incorporation of statistical software with real clinical context data would enable the establishment of cognitive bridges between the abstract content of biostatistics and everyday medical practice, generating substantial connections that favour learning retention and transfer. This approach, combined with problem-based learning (PBL) strategies using clinical cases, could represent a high-impact pedagogical alternative for statistical training in Medicine.

The unanimous identification of structural barriers (infrastructure, institutional policies, lack of training) by teaching staff is consistent with SENESCYT's (2018) findings for the Ecuadorian context, and reinforces the need to address ICT integration not as an individual teacher decision, but as an institutional process requiring clear policies, sustained resources, and ongoing pedagogical support. As noted by Hidalgo-Cajo and Meneses-Freire (2024), technological innovation in higher education is most effective when articulated with teacher wellbeing strategies and working conditions that facilitate dedication to pedagogical renewal.

Among the limitations of the present study is the small sample size, particularly of the teaching staff stratum (n = 3), which limits the generalisation of findings to other institutional contexts. Likewise, the cross-sectional design does not permit the establishment of causal relationships nor the tracking of changes over time. Future studies should incorporate quasi-experimental designs to evaluate the impact of specific ICT interventions on academic performance and students' statistical competence, with larger samples and across multiple institutions.

6. Conclusions

The research findings clearly demonstrate a paradoxical structural situation in biostatistics teaching in Medicine: whilst students exhibit a markedly favourable disposition towards educational technology (84%–90%), teaching staff lack the competencies and conditions necessary to integrate it effectively into their pedagogical practice, and access to specialised digital resources is insufficient for both groups. This gap is not an isolated phenomenon, but rather the concrete expression of systemic deficits in teacher training, institutional policy, and technological infrastructure.

The teaching of biostatistics through active ICT-mediated methodologies should not be conceived as a complementary option, but as an urgent academic necessity, aligned with international quality standards in medical education and with the requirements of evidence-based clinical practice. The statistical competence of future physicians is, ultimately, a clinical competency with direct implications for the safety and quality of healthcare.

To achieve this transformation, at least three articulated institutional conditions are required: (a) continuing teacher training programmes in pedagogical digital competencies, structured according to reference frameworks such as DigCompEdu; (b) development and validation of specific interactive teaching resources for medical biostatistics, contextualised with real clinical data from the local setting; and (c) institutional policies that guarantee adequate technological infrastructure, statistical software licensing, and curricular time for pedagogical innovation.

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From this perspective, the study lays the groundwork for future lines of research aimed at designing, implementing, and evaluating specific ICT interventions in biostatistics teaching, with emphasis on measuring their impact on academic performance, the reduction of mathematical anxiety, and the development of statistical competencies transferable to medical practice. It is hoped that the research findings will contribute to guiding the educational policies of Ecuadorian universities towards systematic, effective, and equitable technological integration in health sciences programmes.

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