Innovation and Digital Transformation in Health Education: Opportunities to Drive Technological Development in the Training of Future Professionals

Innovación y Transformación Digital en la Educación en Salud: Oportunidades para Impulsar el Desarrollo Tecnológico en la Formación de los Futuros Profesionales

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Yelson Alejandro Picón-Jaimes
Fac Ciències Salut Blanquerna, Univ Ramon Llul, Barcelona, España
yelsonalejandropj@blanquerna.url.edu

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Abstract
Introduction--- Digital transformation has emerged as a pivotal factor in modernizing health systems and education worldwide. Despite its transformative potential, disparities in access to technology and digital education persist, particularly in low- and middle-income countries, impacting the preparation of future healthcare professionals.
Aim--- To explore the current gaps, challenges, and opportunities in the integration of digital technologies within health education to drive innovation and prepare future professionals for a digitally advanced healthcare landscape.
Methods--- A brief bibliometric analysis was conducted using Scopus to assess global and Latin American research trends in digital health and professional health education.
Results--- Global research on digital health has shown exponential growth since 2016, with the United States and United Kingdom leading production. In Latin America, research remains limited, accounting for only 3.13% of global output. Brazil leads regional efforts, though disparities in institutional contributions and technological access are evident. Digital health education is still a niche, with less than 300 global publications and only 16 originating from Latin America.
Conclusions--- Innovation and digital transformation in health education present unique opportunities to address global disparities and prepare healthcare professionals for emerging challenges. Strengthening technological infrastructure, integrating digital competencies into curricula, and fostering international collaborations are critical to achieving equitable advancements in health education.

Keywords--- Digital Health, Health Sciences, Technology and Innovation Management, Health Education, Interprofessional Education.

Resumen
Introducción--- La transformación digital se ha convertido en un factor clave para la modernización de los sistemas de salud y la educación a nivel global. A pesar de su potencial transformador, persisten desigualdades en el acceso a tecnología y educación digital, especialmente en países de ingresos bajos y medianos, lo que impacta la preparación de los futuros profesionales de la salud.
Objetivo--- Explorar las brechas, desafíos y oportunidades actuales en la integración de tecnologías digitales en la educación en salud para impulsar la innovación y preparar a los futuros profesionales para un entorno sanitario avanzado.
Métodos--- Se realizó un análisis bibliométrico en Scopus para evaluar las tendencias globales y latinoamericanas en investigación sobre salud digital y educación profesional en salud.
Resultados--- La investigación global en salud digital ha mostrado un crecimiento exponencial desde 2016, liderada por Estados Unidos y Reino Unido. En América Latina, la producción es limitada, representando solo el 3,13% del total global. Brasil lidera los esfuerzos regionales, aunque persisten disparidades en las contribuciones institucionales y el acceso tecnológico. La educación en salud digital es aún un nicho, con menos de 300 publicaciones globales y solo 16 provenientes de América Latina.
Conclusiones--- La innovación y transformación digital en la educación en salud representan oportunidades únicas para abordar desigualdades globales y preparar a los profesionales de la salud ante desafíos emergentes. Fortalecer la infraestructura tecnológica, integrar competencias digitales en los currículos y fomentar colaboraciones internacionales son acciones clave para avanzar de manera equitativa en la educación en salud.

Palabras clave--- Salud Digital, Gestión de Ciencia, Tecnología e Innovación en Salud, Educación en Salud, Educación Interprofesional.

I. INTRODUCTION

Digital transformation has been identified as a critical factor in the modernization of health systems and medical education worldwide [1]. Within a constantly evolving landscape of public health needs, the integration of digital technologies into the training of healthcare professionals is regarded not merely as a trend but as an urgent necessity [2]. Nonetheless, this transition remains highly inconsistent. According to the World Health Organization (WHO)'s Global Strategy on Digital Health 2020–2025, more than 50% of low- and middle-income countries encounter significant barriers to adopting digital technologies in their health and education systems [3].

The adoption of tools such as artificial intelligence (AI), virtual reality (VR) and augmented reality (AR)-based simulation, as well as distance learning platforms, has been demonstrated to hold transformative potential for redefining traditional models of health education [4]. Recent scientometric and conceptual analyses have indicated a consistent annual growth in publications related to "digital health and education" over the past decade, underscoring the increasing interest of the scientific community in this field [5, 6].

However, unequal access to these technological innovations continues to exacerbate disparities in the training of healthcare professionals [3]. These disparities directly impact the quality of health services provided and the global indicators of healthcare quality. In the European Union, for instance, 75% of healthcare professionals have access to training in advanced digital competencies, whereas this figure falls below 30% in Latin America and sub-Saharan Africa [7].

Given these challenges, it becomes essential to continuously evaluate and address the obstacles, gaps, and opportunities faced by digital health, particularly in the education of future healthcare professionals. Such efforts are vital to effectively, efficiently, and optimally meet the health needs and priorities of populations. The aim of this manuscript is to analyze the current gaps and opportunities in research on digital health and professional health education.

II. KEY CURRENT CHALLENGES AND THEIR POTENTIAL IMPACT ON HEALTHCARE

The WHO Global Health Observatory has identified chronic non-communicable diseases, specifically cardiovascular diseases, cancer, and chronic respiratory conditions, as leading health challenges [8]. A significant proportion of these deaths is attributed to preventable risk factors, such as elevated blood pressure, pollution, smoking, and hyperglycemia [9]. One of the most pressing challenges remains the real-world, particularly community-level, control of these risk factors to mitigate the development or exacerbation of acute and chronic conditions. Over time, advancements in health technologies have enabled risk factors to be addressed through monitoring, intervention, and direct prevention [10].

Data from the World Bank indicate a more than 500% increase in global internet usage over the past decade [12], signaling greater integration with technologies and communication networks. Innovative strategies have leveraged these channels to deliver health promotion and disease prevention initiatives within communities [12]. Robust evidence has demonstrated the potential of digital health research and development as tools for health education and intervention, breaking down traditional barriers to timely and quality healthcare access [13].

Low- and middle-income countries face the greatest challenges in implementing digital health strategies to improve health indicators through technology-driven interventions. Several key obstacles remain:

- ***Disparities in access to technology:*** Inadequate technological infrastructure persists as a fundamental barrier, particularly in resource-limited settings. Low-income regions continue to struggle with limited connectivity, high costs of technological devices, and insufficient training for effective use of these tools [14]. This imbalance directly affects equity in learning and the quality of healthcare future professionals can provide.
- ***Resistance to change:*** Despite demonstrated benefits, significant resistance to the adoption of digital technologies is still observed among educators and institutions. The position of some health educators—who consider digital platforms to be less effective than face-to-face methods despite evidence suggesting otherwise [15]—has been previously dis-

cussed. Rejection in the implementation of digital health transitions is also caused by other barriers, such as personal issues, psychological factors, and work overload among health professionals [16]. These issues should be explored in a personalized and contextualized manner to seek definitive and reproducible solutions at the local level.

- ***Lack of standardization in digital competencies:*** The "Global Strategy on Digital Health" emphasizes that digital competencies must be integrated as an essential component in the training of health professionals [3]. However, a considerable gap is observed between countries in terms of definitions, content, and assessment of these competencies. While robust initiatives such as the Digital Competence Framework for Educators (DigCompEdu) are present in Europe, such frameworks are scarce or nonexistent in Latin America and sub-Saharan Africa [3].
- ***Traceability in health indicators:*** The capacity of health systems to respond efficiently to contemporary challenges is directly impacted by the lack of training and fragmented digital transition. Consequently, a significant gap in the recognition of health indicators that can be continuously evaluated is generated, hindering higher levels of continuity in healthcare delivery and the education of new professionals. This may be one of the reasons why, during the COVID-19 pandemic, a 30% increase in interruptions of essential health services was reported in regions with low levels of digitization [17].

III. GAPS AND OPPORTUNITIES IN DIGITAL HEALTH AND HEALTH EDUCATION IN LATIN AMERICA

To examine the background and scientific growth of digital health and its integration into the education of future healthcare professionals, a brief bibliometric analysis was conducted using the Scopus database. The search employed terms derived from MeSH, including "Digital Health" and subcategories of the descriptor "Professional Education," related to professional or continuing education in fields such as medicine, nursing, pharmacy, dentistry, neuroscience, and healthcare professions. Only serial publications in peer-reviewed journals undergoing standard editorial evaluation were included. Excluded documents consisted of book chapters, books, conference papers, and retracted documents. The search was performed on December 13, 2024. Additionally, scientific production by Latin American authors was compared using affiliation country tags to contextualize the related literature. This methodology has been previously employed and validated for assessing research trends and gaps [18-20].

The global evidence on digital health yielded 11,182 results. A notable increase in publications has been observed since 2016, with sustained growth to date (Figure 1A). The United States and the United Kingdom lead scientific production in this area (Figure 1B), with prominent contributions from institutions such as Harvard Medical School and the University of Toronto (Figure 1C). As shown, the majority of publications consist of research articles (Figure 1D), highlighting the originality in developing experimental ideas, likely attributed to the multidisciplinary nature inherent to digital health.

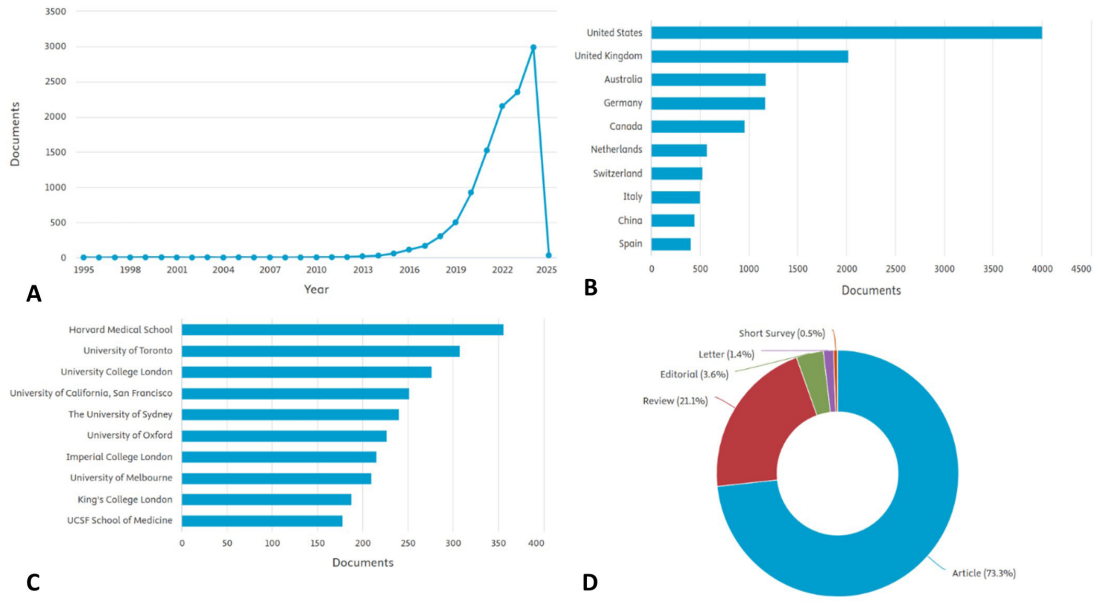

Fig. 1. Evolution and characteristics of global research on digital health. A. Scientific growth over time. B. Most prolific countries. C. Most prolific institutions. D. Distribution of scientific output by publication type.

Filtering by Latin American countries revealed that the region accounted for only 3.13% (n=350) of the total scientific production, with marked and sustained growth observed starting in 2019 (Figure 2A), a few years behind the global trend. Brazil emerged as the leading country in the region, followed by Mexico and Chile (Figure 2B). Among the top 10 most active institutions in this field within Latin America, nine are located in Brazil, underscoring its regional dominance (Figure 2C). Regarding the disciplines contributing to this evidence, the majority of research has been conducted in Medicine (62.9%), followed by Nursing (6.8%) (Figure 2D).

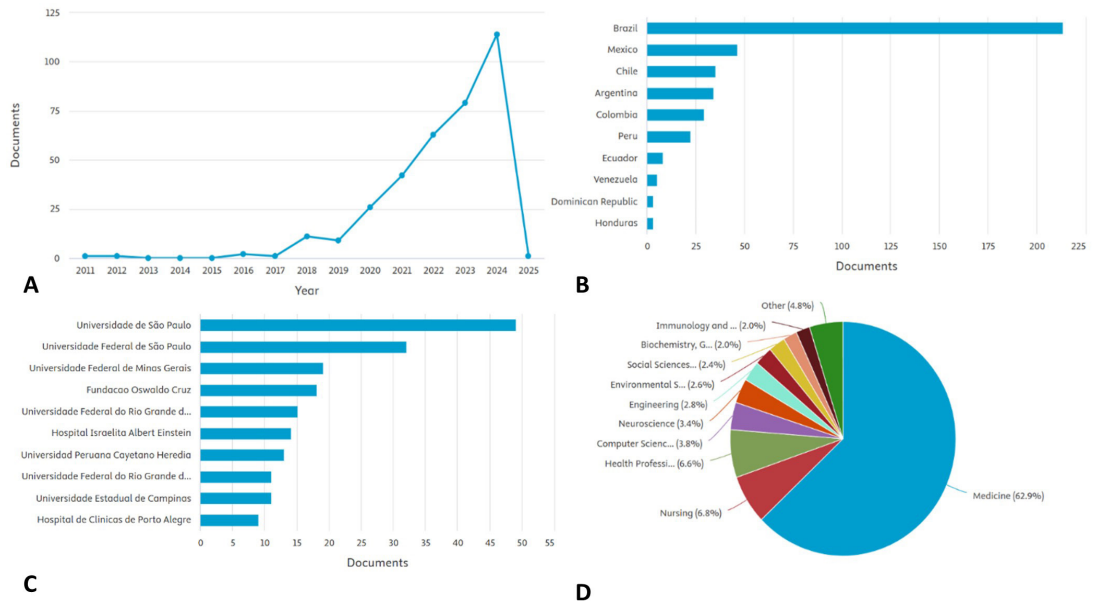

Fig 2. Evolution and characteristics of Latin American research on digital health. A. Scientific growth over time. B. Most prolific countries. C. Most prolific institutions. D. Distribution of publications by research area

When examining evidence on digital health specifically linked to the professional education of healthcare providers, a markedly different scenario emerges. Globally, only 293 scientific documents have been published, with notable progress beginning in 2018 (Figure 3A). This area is again led by the United States and the United Kingdom (Figure 3B). Medicine and nursing represent the most frequently explored fields (Figure 3C). In this context, the leading institutions are more diverse, including organizations from Asia, Europe, and North America (Figure 3D).

Scientific production in Latin America on digital health and the education of healthcare professionals remains notably limited, with only 16 documents representing 5.46% of the total publications on digital health and professional health education, and just 0.14% (n=16/11,182) of the global evidence on digital health. This topic clearly represents a niche for transformative innovation that requires further exploration to generate valuable interdisciplinary knowledge spanning health, innovation, education, and productivity.

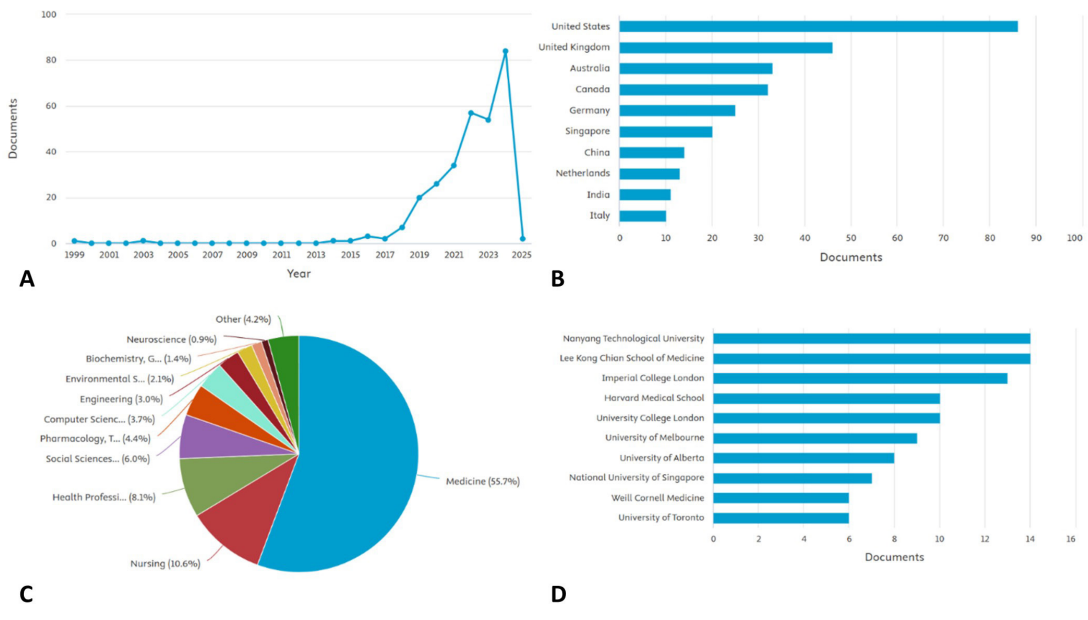

Fig 3. Evolution and characteristics of global research on digital health and professional health education . A. Scientific growth over time. B. Most prolific countries. C. Distribution of publications by research area. D. Most prolific institutions.

The literature highlights several strategies that could be implemented in Latin America, including Colombia, to address challenges in digital health implementation and its integration into professional healthcare education [21,22]:

1) Strengthening technological infrastructure: Investments must be prioritized to ensure equitable access to digital platforms. This involves not only improving internet connectivity but also promoting subsidies for the acquisition of devices and technological tools in resource-limited regions [23].

2) Integrating digital competencies into curricula: Educational systems for healthcare professionals should restructure curricula to incorporate digital competencies comprehensively. Such efforts would enhance professional preparedness while helping to bridge the technological skills gap between regions [23].

3) Fostering international collaboration: The establishment of global networks for knowledge exchange and best practices in digital health is essential. Initiatives such as the WHO's Strategic Partners' Initiative for Data and Digital Health provide models for collaborations that transcend borders and economic contexts [24]. Figures 1C, 2C, and 3D identify potential collaborators with expertise and a track record of generating innovative evidence.

4) Evaluating and adapting emerging technologies: Emerging tools such as artificial intelligence and machine learning hold significant potential to transform health education. However, their adoption must be accompanied by rigorous evaluations to ensure effectiveness and equity. The application of these technologies could substantially reduce the time required for training in critical clinical skills [25].

In alignment with international standards, efforts, resources, and human talent must be directed toward innovative projects and technological strategies with real-world impacts on health indicators [26]. Digital health interventions and the integration of digital health into professional healthcare education represent two critical areas requiring in-depth research and support for their development.

IV. CONCLUSIONS

Innovation and digital transformation present an unprecedented opportunity to revolutionize health education and reduce global disparities in the training of healthcare professionals. Achieving this goal requires addressing current challenges through a strategic and collaborative approach, supported by scientific evidence and coordinated efforts among governments, educational institutions, and international organizations. Digital health education must not only be prioritized but also serve as a catalyst for the sustainable and equitable development of health systems worldwide.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Yelson Alejandro Picón-Jaimes: Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing.

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