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REVISÃO DA LITERATURA

Bibliometric analysis on the reduction of the digital divide in university students: trends and perspectives

Análise bibliométrica sobre a redução da exclusão digital entre estudantes universitários: tendências e perspectivas

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Abstract. The bibliometric analysis focuses on bridging the digital divide in university students, a critical issue in today's education that impacts both access to information technologies and the competencies needed for their effective use, affecting students' academic performance and career opportunities. The central objective is to identify the main trends and contributions in the scientific literature on this topic, analysing the evolution of publications, influential authors, leading institutions and international collaborations. To this end, a quantitative methodology of bibliometric mapping based on the Scopus database is used, processing 404 publications through tools such as Bibliometrix and VOSviewer to visualise co-authorship networks and emerging themes. The results show a significant increase in scientific output since 2017, highlighting the influence of the COVID-19 pandemic on the digitisation of education and the urgency of addressing technological inequalities. Key findings indicate that, while the digital divide remains a global challenge, international collaboration and education policies focused on digital equity are essential to mitigate these inequalities, ensuring equal access to digital technologies for all university students.

Keyword: Digital divide. Education. University students. Education policies. Digital equity.

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Resumo. A análise bibliométrica concentra-se na redução da exclusão digital entre estudantes universitários, um tema crítico na educação contemporânea que impacta tanto o acesso às tecnologias da informação quanto as competências necessárias para seu uso eficaz, afetando o desempenho acadêmico e as oportunidades profissionais dos estudantes. O objetivo central é identificar as principais tendências e contribuições na literatura científica sobre esse tema, analisando a evolução das publicações, os autores mais influentes, as instituições líderes e as colaborações internacionais. Para isso, emprega-se uma metodologia quantitativa de mapeamento bibliométrico baseada na base de dados Scopus, processando 404 publicações por meio de ferramentas como o Bibliometrix e o VOSviewer para visualizar redes de coautoria e temas emergentes. Os resultados revelam um aumento significativo na produção científica a partir de 2017, destacando a influência da pandemia de COVID-19 na digitalização da educação e a urgência de enfrentar as desigualdades tecnológicas. As principais conclusões indicam que, embora a exclusão digital continue sendo um desafio global, a colaboração internacional e as políticas educacionais focadas na equidade digital são essenciais para mitigar essas desigualdades, assegurando o acesso igualitário às tecnologias digitais para todos os estudantes universitários.

Palavras-chave: Exclusão digital. Educação. Estudantes universitários. Políticas educacionais. Equidade digital.

Introduction

The digital divide, defined as the disparity in access to, use of, and competencies in information and communication technologies (ICT) (García-Faroldi, 2022), has become a topic of growing interest and concern in both academic and social spheres (López Bueno et al., 2023). In the university context, this divide can significantly influence academic performance (Duche Perez et al., 2019; Zreik, 2023) and students' future opportunities

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(Faura-Martínez et al., 2022). Consequently, students' ability to access digital resources and use them effectively is essential for their academic success (Ortega-Sánchez, 2023), as well as for their professional development in an increasingly digitalized world (Kumi-Yeboah et al., 2023).

The reduction of the digital divide among university students has been the focus of numerous studies, reflecting a wide range of approaches and strategies (Tetteh et al., 2023). These studies address topics ranging from governmental policies and institutional initiatives (Castano et al., 2012; Maphosa & Maphosa, 2023) to technological solutions and pedagogical methodologies (Karunakar, 2021). In this regard, understanding trends and perspectives is crucial for designing effective interventions (Moro et al., 2023), as well as for promoting equity in access to and use of ICT (Maphalala et al., 2021).

During the COVID-19 pandemic, the forced transition to online education exposed significant deficiencies in access to ICT and in digital competencies (Ibrahim et al., 2022), exacerbating digital disparities and highlighting the urgent need to address the digital divide in the educational context (Malik et al., 2022), particularly as it disproportionately affects students from socioeconomically disadvantaged backgrounds (Reisdorf et al., 2020; Diaz-Leon et al., 2023). As a result, this situation has sparked renewed interest in research aimed at mitigating these inequalities (Alkureishi et al., 2021) and ensuring that all students have equal learning opportunities (Wilson et al., 2023).

The growing recognition of the importance of digital skills in the global labor market further underscores the relevance of this issue (Montaña-Blasco et al., 2023). Digital competencies are not only essential for academic success (Carow et al., 2023), but also for employability (Patel, 2022) and active participation in contemporary society (Gladkova et al., 2022). In this regard, investigating and understanding strategies to reduce the digital divide has significant implications at both educational and socioeconomic levels (Mula-Falcón et al., 2023; Alam et al., 2023).

It is important to note that the digital divide does not manifest uniformly across all regions of the world (Keser Aschenberger et al., 2023). In Latin America, the digital divide is influenced by economic, social, and geographic factors (Castillo et al., 2021; Sánchez-Oñate et al., 2023), with particularly notable disparities in internet infrastructure (Arévalo et al., 2022) and access to technological devices (Teixeira et al., 2021). In Africa, the barriers to reducing the digital divide are even more pronounced (Lembani et al., 2020), due to limitations in basic infrastructure (Zimba et al., 2021), high connectivity costs (Azionya & Nhedzi, 2021), and low levels of digital literacy (Msila, 2021). In Asia, although some regions have made significant technological progress (Ibrahim et al., 2022), inequalities persist due to socioeconomic disparities (Jugembayeva & Murzagaliyeva, 2023) and the lack of inclusive educational policies (Choudhury et al., 2023). In Europe, the digital divide is mainly observed between developed and developing countries within the continent (Jacques et al., 2021b), as well as between urban and rural areas (Tirado-Morueta et al., 2023).

This article aims to conduct a bibliometric analysis of the existing literature on the reduction of the digital divide among university students. The objective is to identify prevailing trends, emerging topics, and key contributions in this field. Using bibliometric techniques, the study

will examine relevant publications, the most influential authors, leading institutions, and patterns of international collaboration. In addition, the temporal evolution of the research and the most prominent thematic areas will be analyzed, providing a comprehensive overview of the progress and challenges in this domain.

Understanding the complexity of reducing the digital divide among university students—and designing effective interventions to improve educational policies—requires, first, a broader understanding of the theoretical and methodological advancements in this field, as well as the historical trajectory of knowledge development surrounding this phenomenon. This analysis leads to the following research question: What is the level of scientific knowledge on the reduction of the digital divide among university students over time? Within this overarching question, the following specific questions are addressed:

i) What is the publication trend over time on the reduction of the digital divide among university students?

ii) Who are the most prominent authors related to this topic?

iii) Which are the most relevant journals in this field?

iv) Which institutional affiliations are most influential in this area?

v) Which countries lead in the production of publications on the digital divide in university education?

vi) How has the frequency of keywords related to the digital divide among university students evolved?

vii) What are the academic fields most closely associated with this topic?

viii) What are the main co-occurring keywords in the research on the digital divide in university education, and how are they interconnected?

ix) What are the future research perspectives on the reduction of the digital divide in the university context?

Methodology

To understand the scientific approach related to reducing the digital divide among university students, a bibliometric mapping methodology was employed. This mathematical and statistical approach enables the analysis of scientific production and the various forms of communication in science (Gómez-Morales, 2015; Laudano et al., 2018). Bibliometrics is applied through a series of systematic and rigorous steps, beginning with the formulation of research questions, the identification of relevant databases, the creation of a canonical search equation, and the statistical and mathematical analysis of the resulting metadata (Bellido-Valdiviezo et al., 2023; Martens et al., 2016).

The research approach adopted was quantitative, focusing on the exploration and description of the scientific study process of the investigated phenomenon. A non-experimental, longitudinal design was selected, ideal for understanding trends and perspectives within the

field, enabling historical tracking of academic output and comprehension of how scholarly attention to the digital divide in higher education has evolved over time.

Based on the research question, a canonical search equation was developed in the Scopus database, incorporating relevant keywords: (TITLE-ABS-KEY ("digital divide" OR "digital gap" OR "technological gap" OR "digitisation gap") AND TITLE-ABS-KEY (university OR "university students" OR "young people") AND TITLE-ABS-KEY (education)) AND PUBYEAR > 1997 AND PUBYEAR < 2024 AND (LIMIT-TO (SUBJAREA, "SOCI")). It is important to note that no specific time frame was applied, as the intention was to trace the development of the topic from its emergence in scientific discourse up to 2023. Scopus was selected due to its multidisciplinary scope and the rigorous peer-review processes it employs. This search yielded a total of 404 scientific publications.

The data retrieved from Scopus were exported in CSV (Comma-Separated Values) format for mathematical and statistical analysis to answer the established research questions (Sulphey et al., 2024). These data were then converted into Excel spreadsheets to facilitate more detailed statistical and mathematical processing and interpretation (Osemwegie et al., 2023).

Since the Scopus metadata records include multiple relationships—such as links between authors, institutions, countries, affiliations, journals, and funders—scientific maps were visualized as co-authorship and semantic networks (Prahani et al., 2024). These visualizations and mappings were generated using specialized open-access software tools such as Bibliometrix and VOSviewer (Shaw et al., 2024).

Bibliometrix is a tool developed in R, a programming language designed for statistical analysis and graphical visualization. It is supported by the R Core Team, which continuously improves the R language, and by the R Foundation for Statistical Computing, a non-profit organization that promotes its use in scientific and statistical research (Aria & Cuccurullo, 2024). To use Bibliometrix, both R and RStudio must be installed (Bellido-Valdiviezo et al., 2023).

VOSviewer, on the other hand, is an open-source software developed by Leiden University in the Netherlands, specifically designed to construct and visualize bibliometric networks. These networks can represent journals, researchers, or publications based on citation, co-citation, bibliographic coupling, or co-authorship relationships (Van Eck & Waltman, 2024). Additionally, VOSviewer features text mining functionality, allowing users to build and visualize term co-occurrence networks extracted from scientific literature (Sulphey et al., 2024).

Results and Discussion

The search strategy employed for the bibliometric analysis related to the reduction of the digital divide among university students yielded a total of 404 documents published between 1998 and 2023, according to the Scopus database, which was selected for its scientific rigor and multidisciplinary coverage. This dataset comprises 307 journals and 1,022 authors, with an international co-authorship rate of 16.58%, an average of 2.68 co-authors per document,

a mean article age of 6.99 years (based on document impact years), and an average of 14.92 citations per article (see Figure 1).

The number of citations received by the analyzed documents clearly indicates the level of interest and recognition these works have garnered within the scientific community. An average of 14.92 citations per document suggests that research on the digital divide is not only widely consulted but also regarded as a key reference in subsequent studies. This underscores both the relevance of the topic and the quality of the contributions made in this field.

Figure 1. Main Information.

The bibliometric analysis reveals a significant rise in research on the reduction of the digital divide over the past decade. This increase coincides with the acceleration of digitalization in the education sector, a phenomenon intensified by the COVID-19 pandemic (Diaz-Leon et al., 2023). The global health emergency forced a rapid shift to online education, exposing inequalities in access to and use of ICT (Bonilla-Del-río & Sánchez Calero, 2022). This context fueled growing academic interest and a substantial output of research focused on mitigating the digital divide (Ayoo, 2022).

The findings from the bibliometric analysis provide a rigorous overview of efforts to reduce the digital divide in higher education. The identification of trends (such as the rise in research activity in the last decade) and patterns (such as high levels of international collaboration and scientific recognition) enables researchers and policymakers to better understand the dynamics of the field (Matsilele, 2021). Such understanding is essential for designing effective interventions that promote digital equity and ensure that all university students have equal access to ICT (Roda & Perry, 2021), regardless of their socioeconomic or geographic backgrounds (Carow et al., 2023).

The temporal evolution of publications addressing the digital divide among university students, analyzed from 1998 to 2023 (see Figure 2), shows an initial period of slow growth in research output between 1998 and 2016. During this time, publications increased gradually, likely reflecting the progressive adoption of information and communication technologies (ICT) in the education sector (Mohan et al., 2020). However, beginning in 2017, scientific output shows greater momentum, reaching a record of 71 documents in 2023. This substantial growth in publications coincides with several key factors: increasing awareness of

the importance of digital equity (Pittman et al., 2020), the impact of educational policies aimed at technological integration, and the COVID-19 pandemic (Faloye et al., 2020), which accelerated the digitalization of education and highlighted existing inequalities in ICT access (Cabero-Almenara & Llorente-Cejudo, 2020). Furthermore, this surge in research suggests a growing recognition of the digital divide as a critical issue that must be addressed to ensure inclusion and academic success for all students.

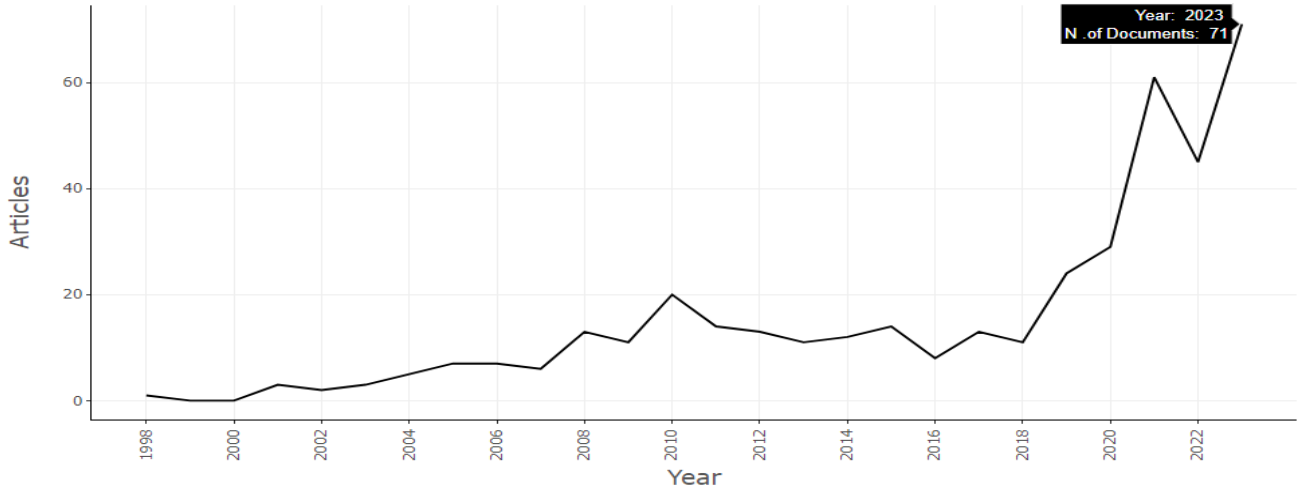

Figure 2. Annual Scientific Production.

Regarding the most distinguished authors in this collection (see Figure 3), prominent researchers include Farley H. from the University of Southern Queensland, Australia; Aguaded-Gómez J. from the University of Huelva, Spain; Ahmad N. from Aligarh Muslim University, India; and Alam M. from the University of Dhaka, Bangladesh, among others. These authors have not only made significant contributions to the body of knowledge on the digital divide but have also led influential research that has been widely cited in the literature. Their work encompasses a variety of approaches and contexts, reflecting the global and multifaceted nature of the digital divide issue (Alam et al., 2023). Moreover, the geographic diversity of these researchers highlights the universal concern for digital equity in higher education (Lowenthal et al., 2020; Pashentsev, 2021).

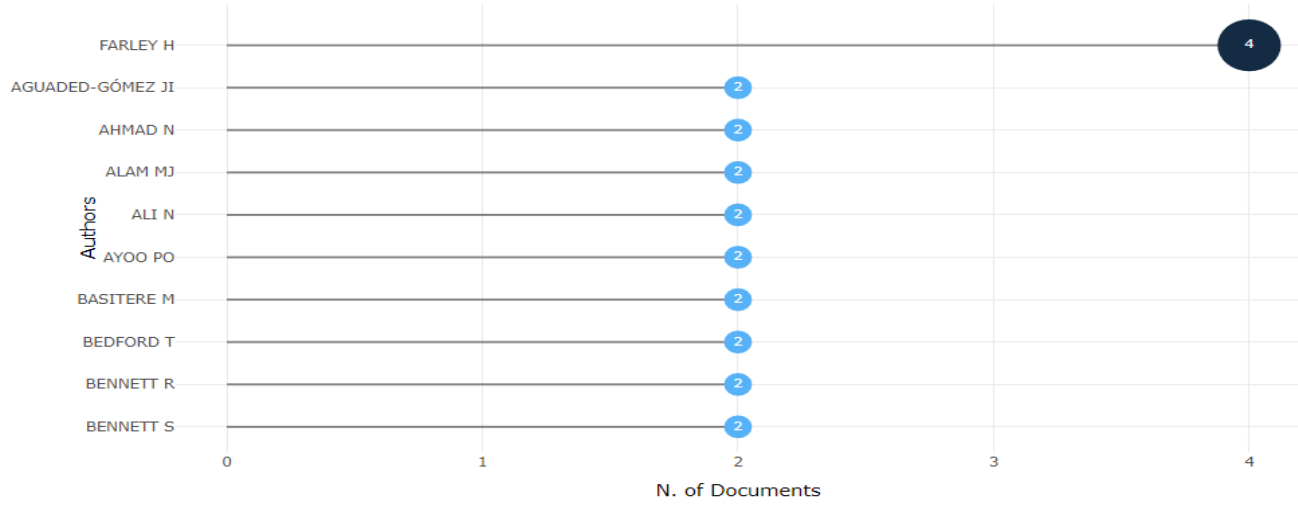

Figure 3. Relevant Authors.

The most prominent journals in the field of digital divide reduction (see Figure 4) include Sustainability (Switzerland), Information Communication and Society (United Kingdom), Comunicar (Spain), and the Turkish Online Journal of Distance Education (Turkey), all indexed in Scopus within the Q1 quartile. These journals not only provide high-visibility platforms for research dissemination but also represent the intersection of disciplines that address the digital divide from various perspectives, such as sustainability, communication, education, and technology (Gant, 2020). The inclusion of high-impact journals in the analysis indicates that research on the digital divide is reaching broad and diverse academic audiences (Mashau & Farisani, 2023), which is essential for driving changes in educational policy and practice (Reisdorf et al., 2020).

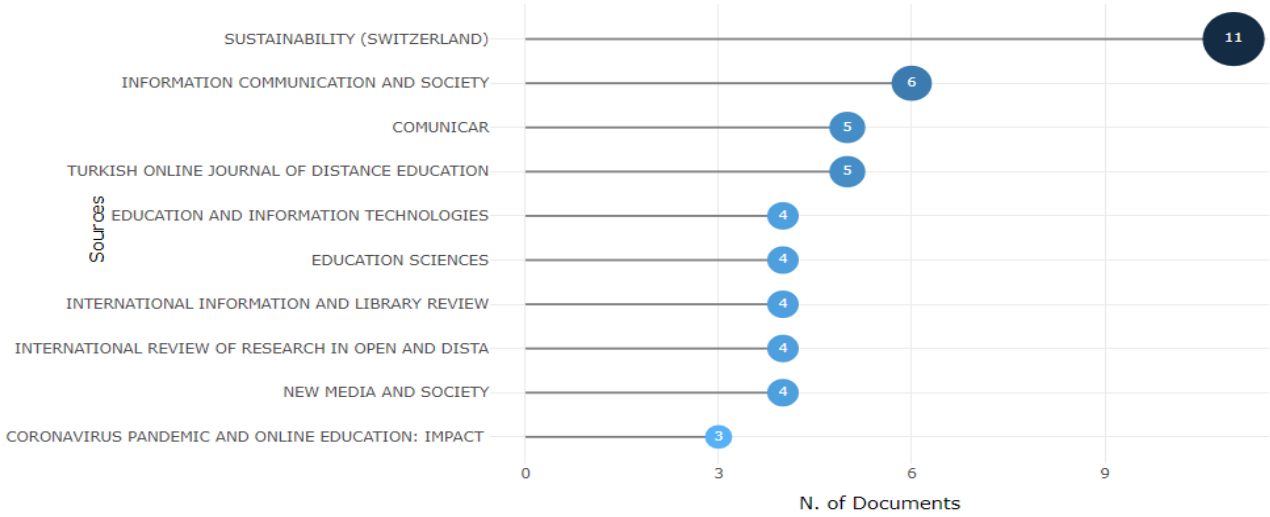

Figure 4. Leading Journals.

The most relevant institutions hosting the leading researchers in the field include the University of South Africa (South Africa), the University of Southern Queensland (Australia), the University of the South Pacific (Fiji – Oceania), and the Universitat Oberta de Catalunya (Spain), among others (see Figure 5). These institutions have played a fundamental role in advancing research on the digital divide by providing the academic support and resources necessary to conduct high-quality studies (Faloye et al., 2020). The presence of universities from different continents reflects the global interest and commitment to addressing digital inequalities (Ndlangamandla, 2022). Furthermore, collaboration among these institutions and the diversity of their approaches contribute to a more comprehensive and nuanced understanding of the issue (Dar & Jan, 2022).

The countries that have made the most significant contributions are the United States, with 62 articles, followed by Spain (59), South Africa (39), the United Kingdom (29), and Australia (28) (see Figure 6). These countries lead scientific production in the field, reflecting their commitment and the resources allocated to addressing this issue. The prominence of the United States and Spain can be attributed to several factors. The United States has a robust technological infrastructure, and digital education policies have driven numerous research efforts (Reisdorf et al., 2020). Additionally, U.S. institutions often have access to extensive resources and funding, enabling large-scale, high-quality studies (Miller, 2021). In the case

of Spain, there has been a sustained interest in digital inclusion, with educational policies and research projects focused on equity in ICT access (Lantarón et al., 2021).

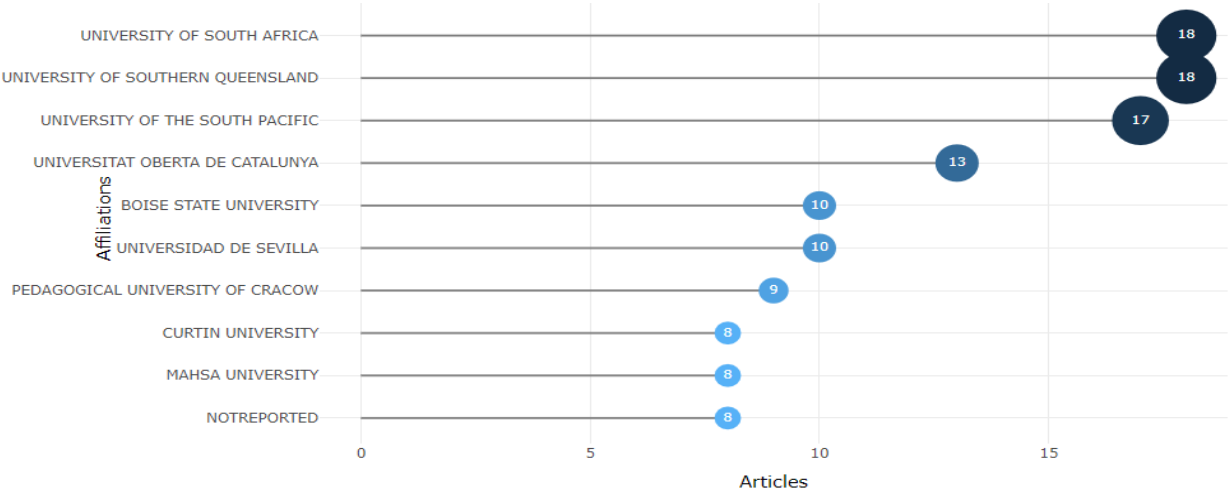

Figure 5. Institutional Affiliations.

South Africa, the United Kingdom, and Australia also contribute significantly, underscoring the global nature of the digital divide (Lembani et al., 2020). It is also important to highlight that there are representatives from every continent, emphasizing the universality of this challenge and the need for solutions tailored to diverse geographic and socioeconomic contexts (Haslop et al., 2021).

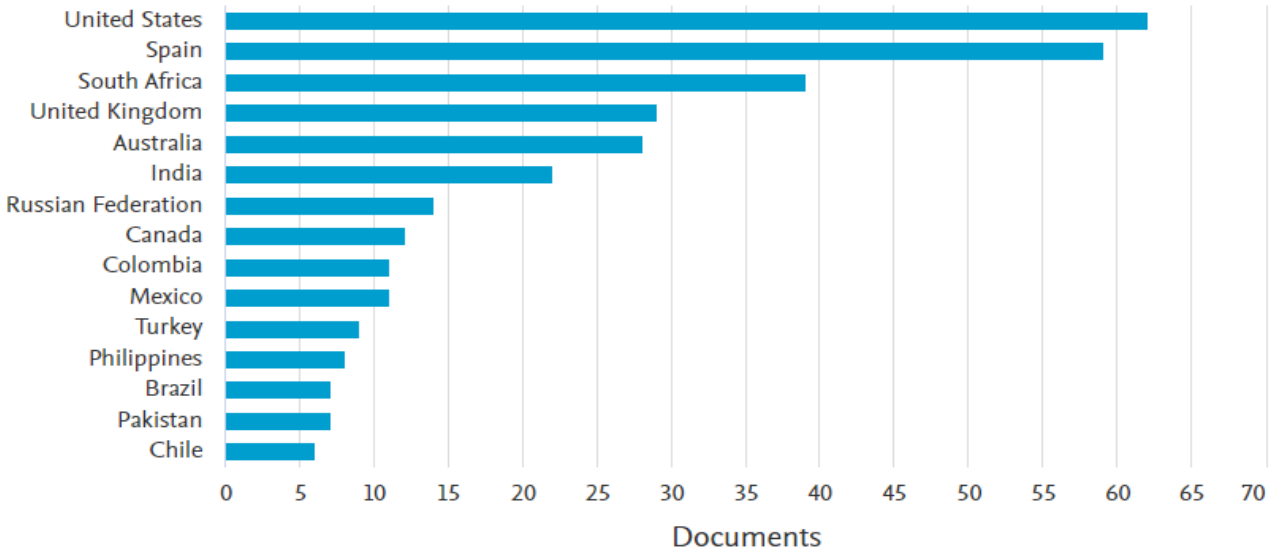

Figure 6. Scientific Production by Country.

The most prominent themes in research on the reduction of the digital divide include 'Students' with 46 occurrences, 'Digital Divide' (40), 'E-Learning' (33), 'Engineering Education' (30), and 'Education' (27) (see Figure 7). These themes reflect the most frequently explored areas and the evolution of academic interest in these issues from 1998 to 2023.

In this regard, the high frequency of 'Students' indicates a strong focus on this group as the most affected by the digital divide (García-Vandewalle García et al., 2022). Research particularly examines how inequalities in access to ICT impact students' academic performance and learning opportunities (Haidi & Hamdan, 2023). The high occurrence of 'Digital Divide' as a key phrase further underscores the central importance of the topic itself, which is a complex phenomenon involving disparities in access, use, and digital skills (Pittman et al., 2020).

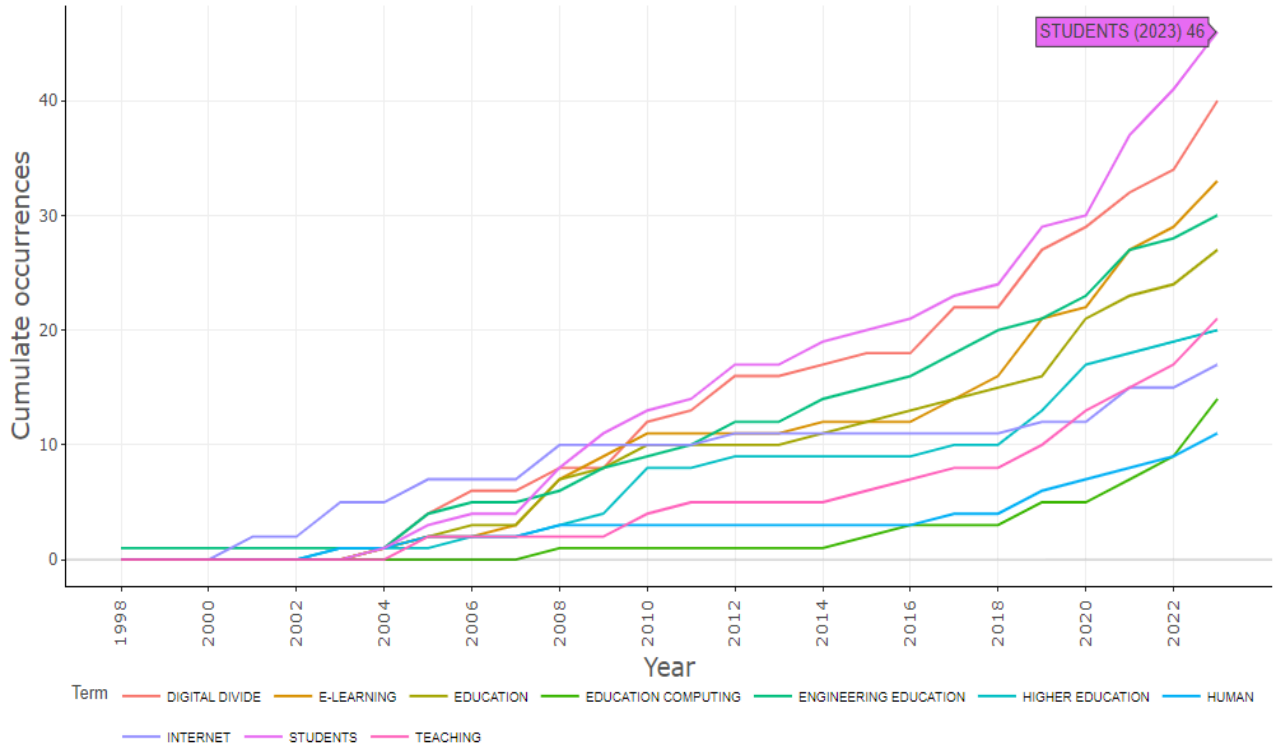

Figure 7. Term Frequency Over Time.

Moreover, the rise in research on 'E-Learning' reflects the transition toward digital education and the need to understand how online platforms can either mitigate or exacerbate digital inequalities (Zreik, 2023). The prominence of 'Engineering Education' suggests a specific interest in how engineering education (a discipline highly dependent on ICT) addresses and responds to the digital divide (Diaz-Leon et al., 2023). Finally, 'Education' remains a core theme, with research focusing on policies, practices, and solutions to equitably integrate ICT across all levels of education (García-Faroldi, 2022).

The most relevant fields of study related to the reduction of the digital divide among university students are diverse and span multiple disciplines. According to the data, these areas include social sciences (58.7%), computer science (15.3%), engineering (5.7%), and arts and humanities (5.4%) (see Figure 8). In this regard, social sciences dominate research on the digital divide (Vishnu et al., 2022). This emphasis reflects the multidimensional nature of the issue, which involves not only technical aspects but also social, economic, and cultural factors (Pittman et al., 2020). Research in this field explores topics such as unequal access to ICT, the social implications of the digital divide, and the policies needed to address these inequalities (Haidi & Hamdan, 2023).

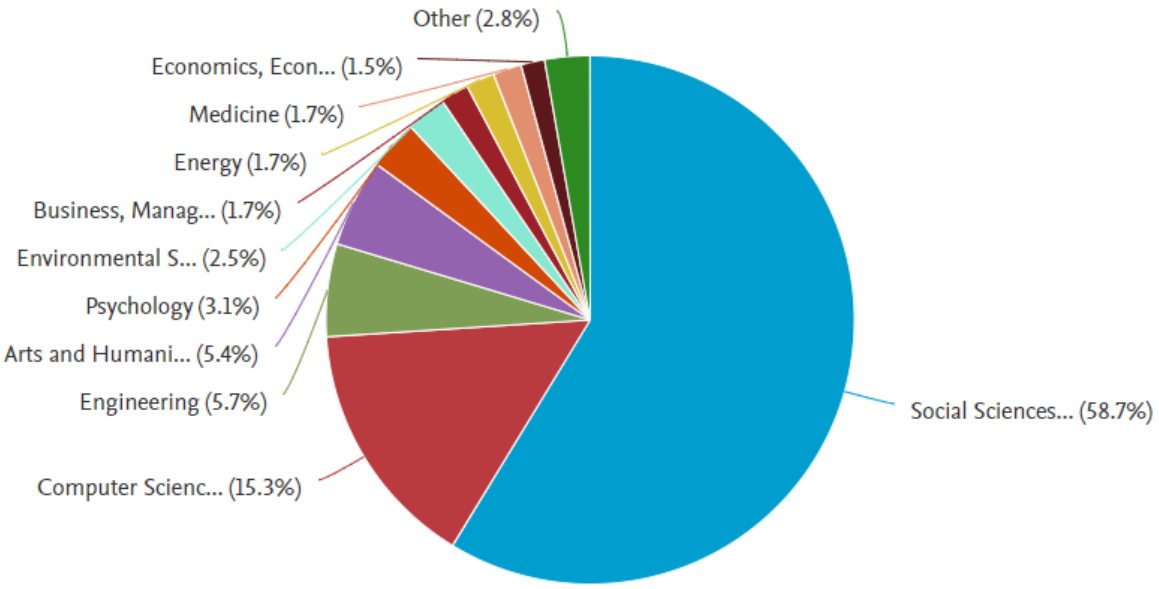

Figure 8. Publications by Field of Study.

Computer science represents the second most relevant discipline. This field focuses on the development and evaluation of digital technologies and solutions that can help bridge the gap through the design of online learning platforms (Blunt & Pearson, 2021), digital literacy tools, and accessible technologies (Gougeon & Cross, 2021).

Engineering also plays a crucial role, as research in this area often centers on the development of technological infrastructures and innovative solutions to improve ICT access (Sastre-Merino et al., 2021), particularly in underrepresented or resource-limited communities (Jacques et al., 2021a).

Lastly, arts and humanities explore the cultural and educational impact of the digital divide (Tarango et al., 2020). Research may include studies on how ICT influences the teaching and learning of arts and humanities, as well as the preservation and dissemination of digital culture (Ramírez & Ruiz, 2021).

The analysis of the keyword co-occurrence network offers a detailed view of how the topic of the digital divide is interconnected with other key concepts in the literature. Specifically, the term 'digital divide' is linked to eight significant clusters, with the most central and proximal nodes including 'higher education,' 'COVID-19,' 'education,' and 'e-learning' (see Figure 9). These nodes also form prominent clusters in which, over the past five years, key emerging terms include 'online learning,' 'digital competence,' 'digital transformation,' and 'digital literacy.'

The nodes 'Higher Education' and 'Education' reflect the relevance of the digital divide within the educational context. Higher education is a critical area where inequalities in ICT access can have a significant impact on academic performance and professional opportunities (Bennett et al., 2020). Research within this cluster explores how educational institutions can mitigate the digital divide and promote technological inclusion (Lembani et al., 2020). The 'COVID-19' node underscores how the pandemic has exacerbated the digital divide, emphasizing the urgency of addressing disparities in ICT access (Cabero-Almenara &

Llorente-Cejudo, 2020), and reflects the scholarly interest in understanding and mitigating the effects of the pandemic on digital education (Pal & Vanijja, 2020). The 'E-learning' node indicates that online learning is a key solution explored to reduce the digital divide (Dheva Rajan & Fajlul Kareem, 2023), with a focus on how e-learning platforms can be designed and implemented to be more inclusive and accessible (Pinto-Santos et al., 2022).

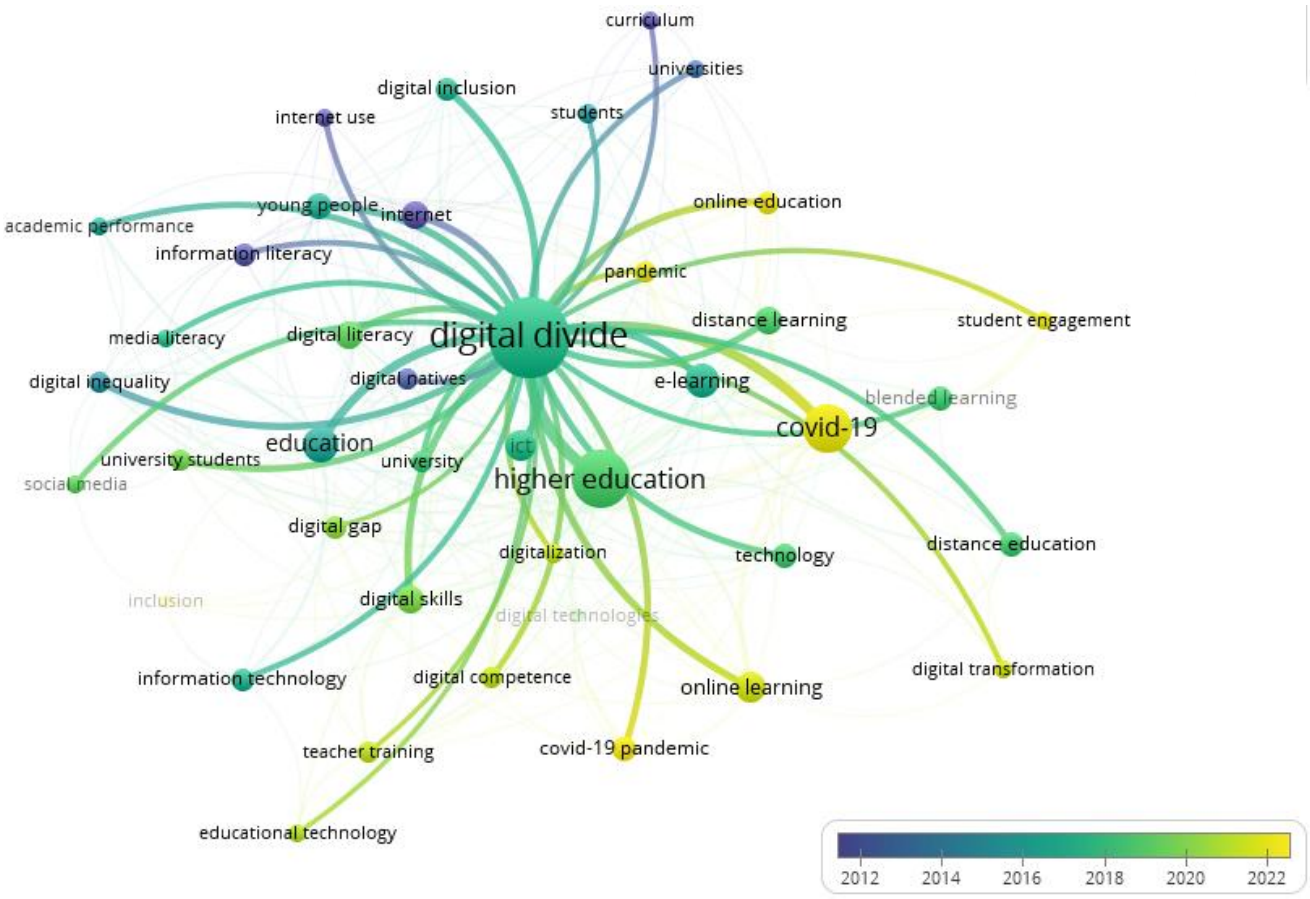

Figure 9. Keyword Co-occurrence Network.

Moreover, significant clusters have emerged as dominant research themes over the past five years. This suggests a growing focus on: 'online learning,' which promotes the development of effective and accessible digital learning methods and platforms (Tomczyk et al., 2020); 'digital competence,' which highlights the importance of having the necessary skills to navigate and use ICT efficiently (Andrés Santiago et al., 2023); 'digital transformation,' which involves structural changes in educational institutions and other sectors driven by digital technology integration (Sastre-Merino et al., 2021); and finally, 'digital literacy,' which emphasizes the need to equip students with the skills required to fully participate in a digitalized society (Barrientos-Báez et al., 2021).

The analysis of the conceptual structure provides a visual representation that allows for understanding the interconnection and relative importance of various themes within the context of the bibliometric analysis (see Figure 10). This visualization is essential for identifying patterns, trends, and areas of focus in research on the reduction of the digital divide among university students.

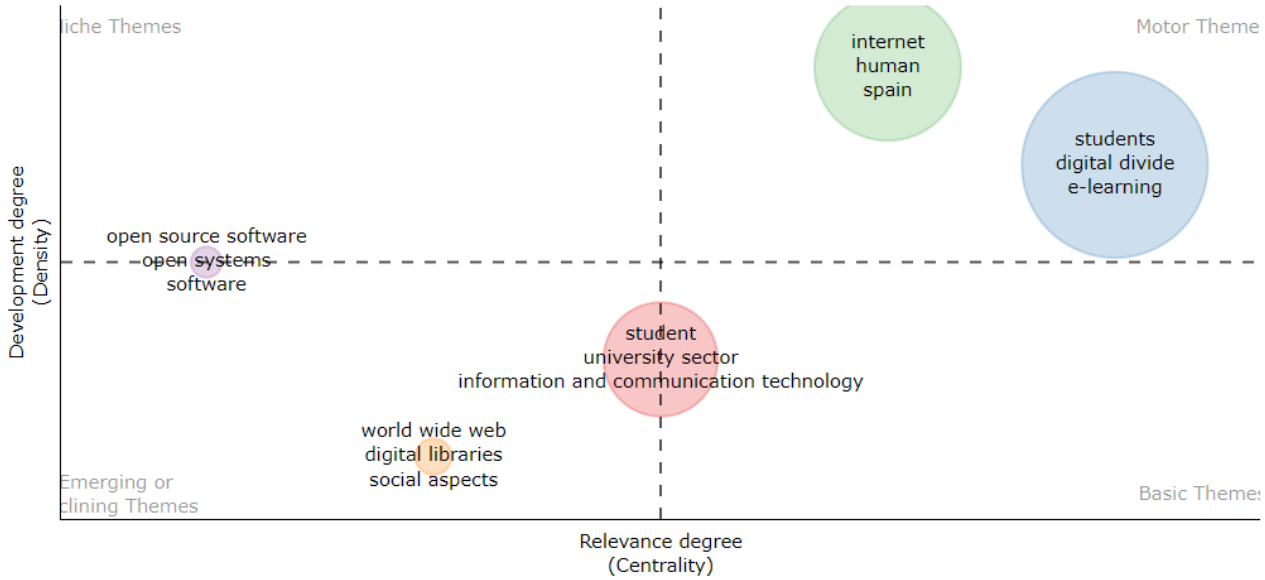

Figure 10. Thematic Map.

The Emerging Themes quadrant presents the formation of three clusters. The first node includes the keywords world wide web, digital libraries, and social aspects, with occurrences of 3, 2, and 2, respectively. The world wide web and digital libraries are essential for accessing and distributing digital information (Matizirofa et al., 2021), while the inclusion of social aspects reflects the impact of these technologies on students' daily lives and personal development (Cáceres-Rodríguez et al., 2022). The second node, shared with the Basic Themes quadrant, contains keywords such as student, university sector, and information and communication technology (ICT), which demonstrate the close relationship between ICT and university students, highlighting the importance of technology in higher education, academic performance, and learning opportunities (Faura-Martínez et al., 2022). On the other hand, the third node, shared with the Niche Themes quadrant, includes keywords like open source software, open systems, and software. These reflect the need for and importance of open-access software in education (Pretorius et al., 2021). Open source software facilitates equitable access to digital tools, which is crucial for reducing the digital divide and promoting technological inclusion (Patino-Toro et al., 2022).

The Motor Themes quadrant comprises two main clusters that highlight core research areas. These themes are central to the field under study due to their strong prominence and interconnectedness. The first cluster includes keywords such as students, digital divide, and e-learning, all of which are foundational to research on the digital divide and emphasize the focus on students, inequalities in technology access, and digital learning (Muchabaiwa & Gondo, 2022). Students is a recurring theme, underscoring that university students are the group most affected by the digital divide (Lim et al., 2020). Digital divide indicates persistent concern about disparities in ICT access (Bennett et al., 2020), and e-learning represents a potential solution to mitigate these inequalities (Tomczyk et al., 2020). The second cluster includes terms such as internet and human, among others. The inclusion of internet reflects its essential role as basic infrastructure for ICT access (Faloye et al., 2020), while human emphasizes the human dimension of the digital divide, reminding us that although

technology is important, the focus must be on how it impacts and improves people's lives (Lowenthal et al., 2020).

Conclusions

Research on the reduction of the digital divide among university students has shown a notable increase from 1998 to 2023, with a significant surge beginning in 2017. This growth coincides with heightened awareness of the importance of digital equity and the impact of the COVID-19 pandemic, which accelerated the digitalization of education and exposed existing inequalities in ICT access.

The most prominent authors in research on the digital divide in higher education are those who have addressed the topic from diverse perspectives, including educational policies, socioeconomic impact, and technological development. These authors have been frequently cited, indicating their influence and significant contributions to the field.

The leading journals in this area include high-impact academic publications focused on education, technology, and public policy. These journals have played a crucial role in disseminating relevant research and fostering debate on how to close the digital divide in the university context.

The most influential universities and research centers in this field are those that have established programs and collaborations focused on digital equity and the integration of ICT in education. These institutions have led studies that provide both theoretical and practical frameworks for addressing the digital divide.

The countries leading the production of publications on the digital divide among university students are primarily those with a strong focus on technological innovation and higher education, including the United States, the United Kingdom, and several European countries.

The frequency of keywords related to the digital divide among university students has evolved significantly, reflecting shifts in research priorities and approaches. Terms such as 'e-learning,' 'ICT,' and 'digital equity' have gained prominence, particularly in the context of the pandemic.

The main fields of knowledge linked to the reduction of the digital divide in higher education include social sciences, computer science, engineering, and the arts and humanities. These disciplines address the issue from technical, social, cultural, and economic perspectives.

The most frequently co-occurring keywords in digital divide research include 'ICT,' 'higher education,' 'digital equity,' and 'access to technology.' These co-occurrences reflect the interconnection of various dimensions of the issue and their relevance in the development of comprehensive strategies.

Future research on the digital divide in higher education should focus on developing inclusive policies, improving technological infrastructure, and implementing educational programs that promote digital literacy. Additionally, it is crucial to explore new technologies and methodologies that can contribute to greater equity in ICT access and usage.

The level of scientific knowledge on the reduction of the digital divide among university students has advanced significantly in recent decades. The current literature provides a solid foundation for understanding the causes and consequences of the digital divide, as well as for designing effective interventions to ensure digital equity in higher education.

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