Bibliometric Analysis of the Research Landscape in Human-Computer Interaction in Ibero-America

Análisis bibliométrico del panorama de la investigación de la interacción humano-computadora en Iberoamérica

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Abstract

Human-Computer Interaction (HCI) is a research discipline that optimizes human-machine interfaces. Ibero-America has become a leading region in HCI advances adapted to its unique socioeconomic environment. However, a global characterization of the research landscape for this discipline in the region still needs to be improved. Therefore, this study aimed to analyze the scientific literature on HCI in Ibero-America using bibliometric techniques, identifying key authors, institutions, conceptual structure, and research trends. The methodology employed consisted of a bibliometric analysis of 9812 documents from 1990-2023 from Scopus and Web of Science. The data were analyzed using Bibliometrix and VOSviewer for statistical and network analysis. The results revealed that Spain, Brazil, Portugal, Mexico, and Colombia are at the forefront of HCI research in the region, with more than 90 % of total publications experiencing an annual growth rate of approximately 14.6 %, driven by strong international collaborations. Key topics are human-computer interaction, virtual reality, augmented reality, and video games, while education is one of the main application areas. The main conclusion is that the HCI research landscape in Ibero-America is characterized by rapid evolution, international integration, and conceptual diversity, indicative of a mature and interdisciplinary field that responds to regional demands. The advancement of the field could be driven by increased private-sector funding. Future system designs in the region should prioritize cultural sensitivity and inclusion.

Keywords

Human-computer Interaction, human–machine system, social engineering, research trends, research collaboration.

Resumen

La interacción humano-computadora es una disciplina centrada en la optimización de las interfaces hombre-máquina. Iberoamérica es una región destacada en cuanto a avances en esta área adaptados a su singular entorno socioeconómico. Sin embargo, aún no se dispone de una caracterización global del panorama investigativo para esta disciplina en la región. Este estudio tuvo como objetivo analizar la literatura científica sobre interacción humano-computadora en Iberoamérica utilizando técnicas bibliométricas, identificando autores clave, instituciones, estructura conceptual y tendencias de investigación. La metodología empleada consistió en un análisis bibliométrico de 9812 documentos del período 1990-2023 provenientes de Scopus y Web of Science. Los datos se analizaron utilizando Bibliometrix y VOSviewer para el análisis estadístico y de redes. Los resultados revelaron que España, Brasil, Portugal, México y Colombia están a la vanguardia de la investigación con más del 90 % del total de publicaciones experimentando una tasa de crecimiento anual de aproximadamente 14,6 %, impulsada por sólidas colaboraciones internacionales. Los temas clave son la interacción humano-computadora, la realidad virtual, la realidad aumentada y los videojuegos, mientras que la educación es una de las principales áreas de aplicación. La principal conclusión es que el panorama de la investigación en interacción humano-computadora en Iberoamérica se caracteriza por una rápida evolución, integración internacional y diversidad conceptual, indicativo de un campo maduro e interdisciplinario que responde a las demandas regionales. El avance de este campo podría verse impulsado por una mayor financiación del sector privado. Los futuros diseños de sistemas en la región deberían priorizar la sensibilidad cultural y la inclusión.

Palabras clave

Interacción humano-computadora, sistema hombre-máquina, ingeniería social, tendencias de investigación, colaboración en investigación.

1.   INTRODUCTION

HCI is a discipline focusing on the design of computer technology and the interaction between humans and computers. HCI focuses primarily on the design of computer interfaces that meet the user's needs, minimizing any unnecessary physical or mental effort during the intervention with the devices [1]. This field is essential, considering that by January 2023, about 5160 million people, constituting 64.4 % of the world's population, are expected to access the internet through digital devices [2]. In addition, an estimated 4.76 billion people worldwide use social networks, and the number of mobile devices in use is expected to reach 18.22 billion by 2025 [3]. Therefore, it is crucial to consider the elements, guidelines, and other concepts defined in HCI when designing digital products to avoid inappropriate designs that could affect users [4].

The United States and China are currently at the forefront of research productivity in this field [5]. In parallel, Ibero-American countries are progressively establishing themselves as an emerging region dedicated to developing strategies to improve the use of digital devices in various demographic groups. The focus of this community is to understand the unique needs, preferences, and challenges of the region and propose solutions tailored to the specificities of these countries [6]. Ibero-America is characterized by a set of socioeconomic and technical attributes and challenges [7], including linguistic and cultural diversity, a digital divide with more industrialized nations, social inequality, violence, and diverse cultural heritage. In this sense, it is necessary to deepen the understanding of communities in Ibero-American countries and their interaction with information technologies to address the context-specific problems of this region [8]. Therefore, it is important to know the current state of HCI research at the Ibero-American level, as this would allow researchers to assess their status, identify research gaps and opportunities, consolidate networks, and identify emerging technologies and standards that allow the creation of new proposals and support among the different countries leading the different areas of HCI.

Considering the above, bibliometrics is an essential tool used in the academic community and in scientific research that, through quantitative and statistical methods, provides data on different aspects of the scientific literature [9]. Applying bibliometrics in the HCI domain in Ibero-America will allow an understanding of the scientific production in the region, identifying challenges and lines of research and effectively orienting the domain of study [10]. In this line, some bibliometric studies have been conducted on the HCI domain in different contexts, as is the case of [11], who use bibliometric methods to investigate HCI in the Nordic-Baltic countries, where the results revealed that the leading countries are Finland, Sweden, and Denmark. Collaboration with foreign researchers was more frequent than domestic, and research gaps should be reduced by increasing activity in countries with low research output and encouraging collaboration with experienced authors. Similarly, in [12], HCI research was reviewed through a bibliometric analysis, in which a dataset including 962 publications from 1969 to early 2017 was analyzed; the analysis identified 46 significant papers focusing on four main factors: HCI design aspects, data management, user interaction, and psychology and cognition. The study also highlighted recent trends like workplaces, sensors, and wearables.

The study presented in [13] focuses on analyzing HCI, user experience (UX), and usability at the driving level in automobiles, where 2498 articles published between 2000 and 2019, sourced from Web of Science (WOS), were examined using co-word network analysis tools such as BibExcel and CiteSpace. The study's results provided a global understanding of the evolution of UX and usability studies in driving over the past decades. Finally, the study [14]

examined 274 articles published between 2000 and 2021 using bibliometrics to identify research progress, key themes, and future directions in the field. The results indicate that HCI has contributed significantly to developing new research areas, such as multimodal analysis of physiological data and the use of big data-based safety management platforms. Prospects include computer vision, computer simulation, virtual reality, and ergonomics.

The literature review reveals the application of bibliometric techniques in various contexts, domains, and geographic regions for HCI. However, to the authors' knowledge, studies have yet to be applied to HCI in the Ibero-American region, thus creating a gap in knowledge that this study aims to fill. Consequently, the main objective of this study is to analyze the scientific literature produced in the Ibero-American region in the field of human-computer interaction, focusing on identifying key authors, affiliations, the conceptual structure of the field, and emerging research trends.

Finally, this paper constitutes an extended version of the paper initially presented at the IX Jornadas Iberoamericanas de Interacción Humano-Computadora [15] in Argentina. A characterization of the state of the art of research production in the field of HCI in Ibero-America is made, considering authors, trends, and regionally prominent countries. In this line, this article deepens the results, offering a more detailed analysis. It identifies the main entities sponsoring research in this discipline and extends the analysis of the conceptual structure of the field at the Ibero-American level. Consequently, it presents a holistic view of the current state of the field at the regional level.

2. MATERIALS AND METHODS

This study performs a bibliometric analysis of the field of HCI in the Ibero-American region, using descriptive and inferential statistical methods. The objective is to know the status, trends, challenges, and opportunities of HCI research in this region, allowing it to improve its visibility and collaboration, as well as to identify gaps and areas of need for future research efforts [16].

The bibliometric analysis was performed following the guidelines proposed in [17], which provides a scheme to execute this type of statistical analysis within a specific domain. In addition, some guidelines were adapted from the Science Mapping Workflow methodology [18] and accepted as a reference in the exercise of bibliometrics. Also, the study incorporated the proposal of [12], which offers a detailed approach to analyze the HCI domain according to this type of study, and the proposal of [19].

Regarding the primary materials used, Scopus and WOS were primary data sources. Meanwhile, the Bibliometrix library [20] of R and VOSviewer [21] was used to perform the bibliometric analysis. Finally, RStudio [22] and Google Sheets [23] were used to elaborate graphics.

2.1 Information collection

To systematically collect bibliographic data, a search strategy was used, as described in Table 1. Boolean exclusion operators (AND) were not used because we sought to map all the documents on HCI in Ibero-America, in addition to synonyms of the term. The second part of the search string includes exploring the countries that make up the Ibero-American community, including Spain and Portugal.

As mentioned above, the scientific databases Scopus and WOS were used, which are recognized for indexing high-quality documents in engineering [24]. After applying the

search string in both databases, the data were downloaded, and the results were combined using an R algorithm.

Table 1. Search string applied on WOS and Scopus. Source: Created by the authors.

(("human-computer interaction" **OR** "computer-mediated communication" **OR** "human-machine interaction" or "human-based computing" **OR** "human-technology interaction")) **AND** (limit-to (affilcountry , "argentina") **OR** limit-to (affilcountry , "bolivia") **OR** limit-to (affilcountry , "brazil") **OR** limit-to (affilcountry , "chile") **OR** limit-to (affilcountry , "colombia") **OR** limit-to (affilcountry , "costa rica") **OR** limit-to (affilcountry , "cuba") **OR** limit-to (affilcountry , "ecuador") **OR** limit-to (affilcountry , "el salvador") **OR** limit-to (affilcountry , "guatemala") **OR** limit-to (affilcountry , "honduras") **OR** limit-to (affilcountry , "mexico") **OR** limit-to (affilcountry , "panama") **OR** limit-to (affilcountry , "paraguay") **OR** limit-to (affilcountry , "peru") **OR** limit-to (affilcountry , "puerto rico") **OR** limit-to (affilcountry , "dominican republic") **OR** limit-to (affilcountry , "uruguay") **OR** limit-to (affilcountry , "venezuela") **OR** limit-to (affilcountry , "spain") **OR** limit-to (affilcountry , "portugal"))

2.2   Execution of the search

This bibliometric analysis utilized a targeted search approach, examining the titles, abstracts, and keywords of scholarly articles. Peer review was a prerequisite for inclusion to ensure the academic rigor and relevance of the literature in this field. The search was performed on the Scopus and Web of Science databases, which are highly respected and established within the scientific community. The search was not constrained by a specific period and was carried out in May 2023.

The search returned 9817 papers published from 1990 to 2023. To evaluate their pertinence, the titles and abstracts of these articles were scrutinized. Articles with incomplete metadata were discarded, bringing the total down to 9812. Duplicate studies were eliminated, resulting in a unique set of results in the database. Secondary studies were incorporated for data extraction. Lastly, the articles were imported into Bibliometrix and VOSviewer for analysis to ascertain the current status of the research field.

3.   RESULTS AND DISCUSSION

This section details the main findings derived from the research and the descriptive and inferential analysis focused on the field of HCI in Ibero-America. As indicated above, the study emphasized aspects such as the most relevant authors, the most cited articles, the most consulted journals, the scientific production by country, the conceptual structure of the domain and institutional affiliations, and the existing interrelationships within the field. This strategy made it possible to establish a diagnosis of the current state of the research area and to recognize trends, challenges, and opportunities for future research in HCI in the Ibero-American context.

3.1   General information on the domain

In this section, an analysis of scientific publications in HCI in Ibero-America is expressed at a general level (Figure 1). The review covers a time frame from 1990 to 2023 and analyzes 2400 sources, including academic journals and books, totaling 9812 documents published in the specified period. The data reveal an average annual growth rate of 14.65 % in the number of publications, indicating a significant upward trend in research output in this domain over time. Furthermore, the average age of these documents is 8.16 years, suggesting that research in this field is not only relatively recent but also continuously evolving.

Figure 1. General information on the HCI domain in Ibero-America. Source: Created by the authors.

The average number of citations per published document is 9216, suggesting that publications in this domain are highly referenced and valued by the scientific community, as well as an indication that Ibero-America is a reference in this area. The total number of references is 238158, which implies thematic diversity and broad scientific support in these publications. The 9812 documents have 30707 keywords plus and 17232 keywords proposed by the authors. The total number of authors is 21401, which is not necessarily limited to authors from Ibero-America, as networks and collaborations between authors from countries outside the Ibero-American region have been observed.

Regarding collaboration, each paper has an average of 3.83 authors per paper, and the percentage of international co-authorship is 29.11 %, indicating frequent cross-border collaboration in this field of research, suggesting a potential for exchanging ideas through greater international collaboration. Although collaborative work predominates, with an average of 3.83 co-authors per paper, there is also evidence of independent contributions, as seen in the 526 single-authored papers.

The documents found are articles, books, book chapters, conference papers, conference reviews, data papers, editorial letters, reviews, and literature reviews. The research output in the Ibero-American HCI domain totals 9812 documents of various types, including 2282 articles, 34 books, 203 book chapters, and a predominance of 7100 conference papers. The predominance of conference papers suggests a culture of knowledge sharing and rapid dissemination within the community, although there may be an opportunity for further exploration through a greater focus on journal publications.

Considering the results, HCI in Ibero-America is a dynamic and constantly evolving field, with the establishment of collaborative networks between national and international authors allowing this area to grow exponentially in short periods.

3.2 Annual scientific production in the domain

Regarding the annual scientific production in this domain (Figure 2), continuous publications have been recorded for almost 33 years, from 1990 to 2023. The number of published papers has increased, and this trend has accelerated in recent years. Specifically, the highest number of papers was published in 2019, with 1012 papers, followed by 2017 and 2016, with 812 and 781, respectively. On the other hand, the lowest number of papers was found in 1991, with no papers published, suggesting that the domain has been gradually growing. Regarding the distribution of papers by year, the data reveal a unimodal and

positively skewed distribution, with a peak in 2019. In addition, it is essential to note that the 2023 data are not representative of the entire year.
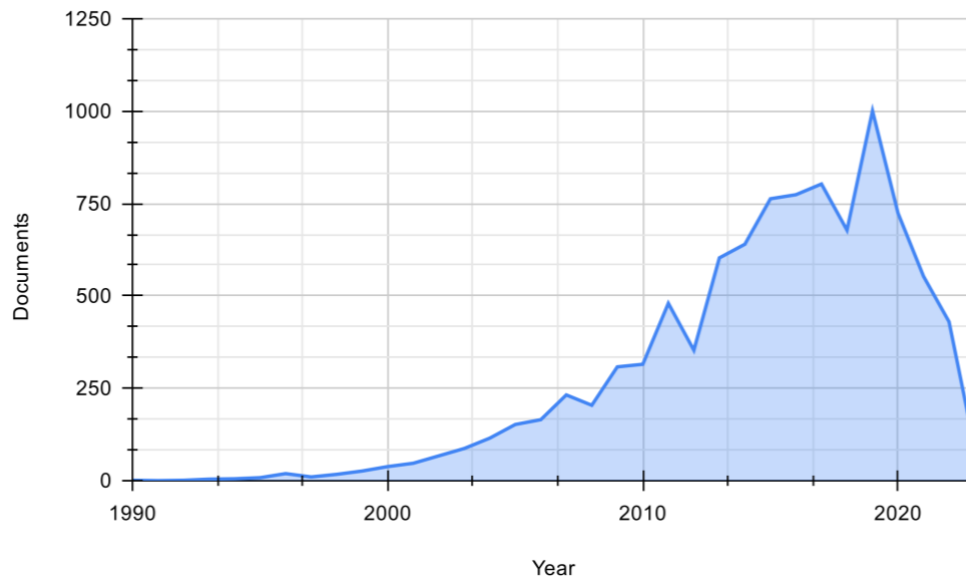

Figure 2. Publications in the HCI domain in Ibero-America from the 1990s to the present.
Source: Created by the authors.

Considering the above, it can be inferred that the increase in scientific publications in the last 30 years in this domain may be due to several factors, such as, for example, an increase in the availability of research funds in the area or the growing recognition of the importance of this field, raising awareness of the need for adequate interaction and therefore the increase in technology in recent decades, in addition to the increase in the number of researchers in Ibero-America and the world [25]. Likewise, it can be indicated that the first ten years (1990-1999) versus the last ten years (2014-2023) shows a difference between the average number of articles per year for the first decade, 9.3 articles/year, while in 2014-2023 it rose to 652 articles/year. This underlines what was said above, which speaks of a constantly expanding domain with clear signs of an accelerated evolution. Finally, the data also suggest that the publication growth will continue in the coming years as more researchers in Ibero-America become interested in this field and more funding becomes available for better results [26].

3.3 Relevant sources in the domain

The HCI domain in Ibero-America has a diverse distribution of journal and conference sources, as shown in Figure 3, which presents about 2400 sources in the domain, of which the 14 most relevant are highlighted. It is important to note that the source with the highest number of published articles is "Lecture Notes in Computer Science (including the subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)", with 2182 articles, which is more than twice the number of articles published by the second most important source, "ACM International Conference Proceeding Series", with 912 articles. These two publications are a series of computer books that publish research results conducted at various conferences, workshops, and research monographs.

The most published sources in this domain, the first six are book series. As for journals, the top two publications in this domain are "Computers in Human Behavior" and "IEEE Access".
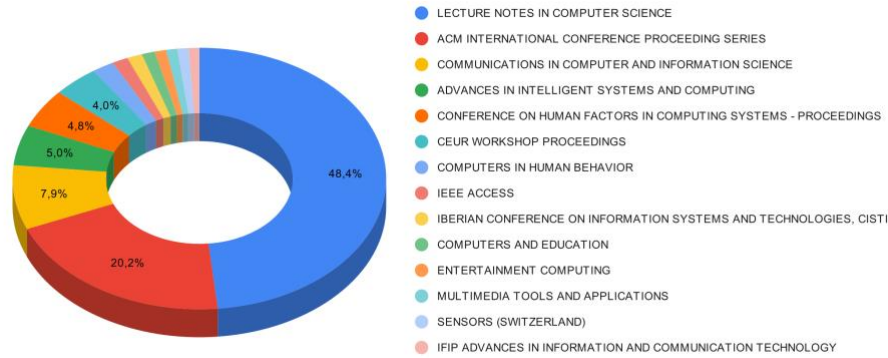
Figure 3. Distribution of sources of journals and conferences in the HCI domain in Ibero-America.
Source: Created by the authors.

The most significant number of publications in the domain are in book series and conferences; this could be because there is a solid academic research community in this field; in addition, this field is characterized by an emphasis on applied research, commonly presented at conferences. Likewise, given that Ibero-American HCI is constantly evolving, it is essential to present the results promptly; publishing in conference proceedings and book series is an efficient way to disseminate new findings, in addition to obtaining immediate feedback, interaction, and networking that arise with other researchers in this type of events, allowing the work to be enriched [27]. In line with the above, the three most productive sources represent approximately 36 % of the total number of papers, indicating that most research is published in a few media and established as referents. This is also evident in the positive asymmetry in the data distribution, where there are few sources with very high productivity and a long tail of other less productive sources.
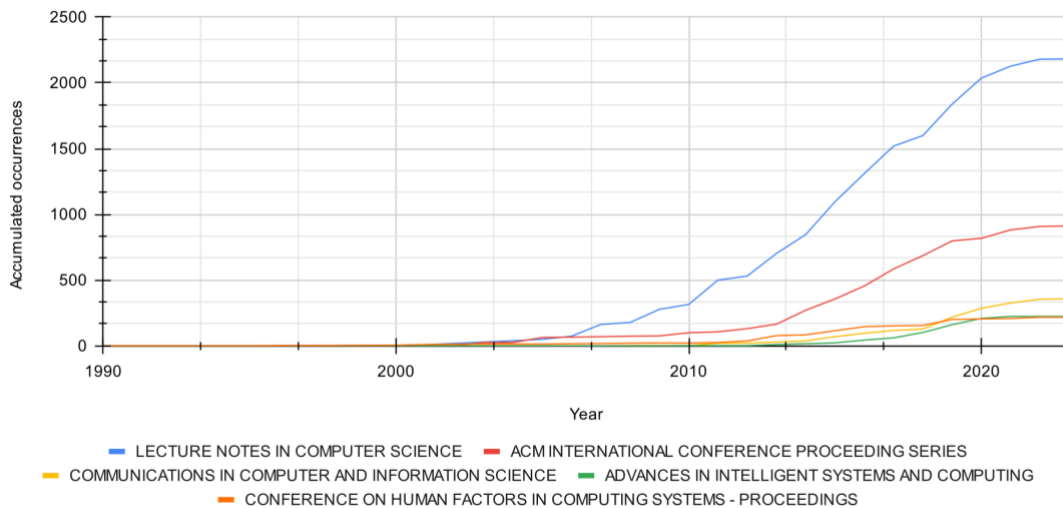

Figure 4. Chronological timeline of the research production of the most relevant sources.
Source: Created by the authors.

The predominant journals for research dissemination are Computers in Human Behavior and IEEE Access, highlighting that these two sources are ranked in the SCImago Journal Rank [28] with the highest rating (Q1), which reflects the relevance of these journals as

significant contributors to this field of study and underlines the relevance of the research conducted in this field.

Figure 4 shows the evolution of the number of publications in the field of HCI in Ibero-America from 1990 to 2023 in various journals and scientific congresses. In the early years, the number of publications was low, but from 2011 onwards, a significant increase is evident, especially in the period from 2010 to 2023, where the source LECTURE NOTES IN COMPUTER SCIENCE stands out above the others. In general, a steady and consistent increase in the number of publications over the years is observed, suggesting that HCI in Ibero-America is constantly developing and receiving increasing attention from the scientific community, in line with previous studies in this area [29].

3.4 Relevant authors in the domain

This section analyzes the most prominent authors in Ibero-America in the field of Ibero-American HCI. In Figure 5, the authors are ordered according to the number of articles published, with Baranauskas from Brazil having the most publications, with 115 articles, and Collazos from Colombia, with 104. Barbosa, Paiva, and Paz, from the list, published between 47 and 73 articles in this domain.

A relevant aspect of this analysis is that Brazil occupies second place as the country that publishes the most in this area, with an outstanding number of authors. In contrast, Spain, the first country to publish in this area, needs authors who have published such a high number of articles, indicating a greater diversity of authors interested in this area in the Iberian country. In addition, it is essential to note that the diversity of authors in this domain and their respective nationalities suggests that research is concentrated in multiple locations, which promotes better research opportunities and international collaboration networks.
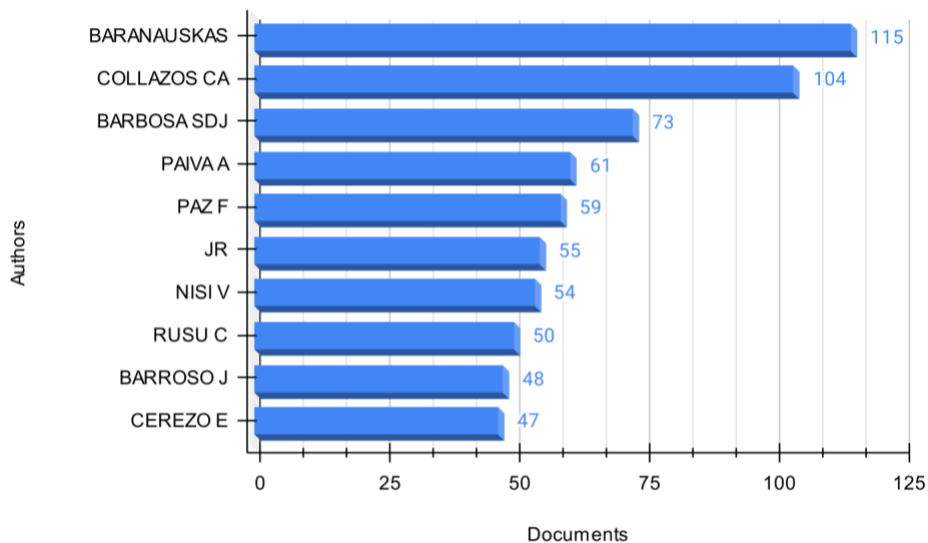

Figure 5. Distribution of the most prominent authors in each domain and their number of publications. Source: Created by the authors.

Regarding the analysis of the production over time of the five most published authors, their publications cover the period between 2000 and 2023, with an average of between 4 and 5 articles per year in this domain. Furthermore, it can be deduced that Baranauskas has a sustained publication cycle spanning from 2000 to 2015, after which he has decreased the number of published research. On the other hand, Paz has increased his number of publications since 2014, peaking with 12 publications in 2021. It can also be observed that Baranauskas has been publishing for 23 consecutive years, which speaks of his constancy in this domain, while Barbosa is in second place with 19 consecutive years of publication. It is important to note that Collazos is the person who has published the highest number of research articles in a calendar year, with a total of 14 in 2017. Finally, the top four authors in the domain have decreased their publications in recent years, indicating a renewal in the research community.

3.5 Most productive countries in the domain

The analysis of productivity by country in the HCI domain in Ibero-America (Figure 6) shows that Spain, Brazil, Portugal, and Mexico are the leading countries in this area. Spain is the outstanding leader with 10769 publications, followed by Brazil with 7977 publications and Portugal with 5200 publications. Mexico, on the other hand, registers approximately half of these publications, with a total of 2355. After the first five countries, production decreases considerably, where Chile has 911 publications, compared to Portugal, for example. It is important to note that the first five countries (Spain, Brazil, Portugal, Mexico, and Colombia) account for more than 90 % of the total number of publications in the regional bloc, which speaks of the importance of the subject matter in the domain for these geographic regions. Finally, the other countries have a comparatively lower research output, with Honduras and Nicaragua having the lowest, with only one publication each.

The first four countries in productivity (Spain, Brazil, Portugal, and Mexico) stand out for having the highest GDPs in the region, as well as for making significant investments in science, technology, and innovation through organizations, so this could be an indication that investment and context are relevant to the domain, as mentioned in the literature [30]. Following these countries are Colombia with 1328 publications, Chile with 911 publications, Ecuador with 610 publications, and Argentina with 525 publications.
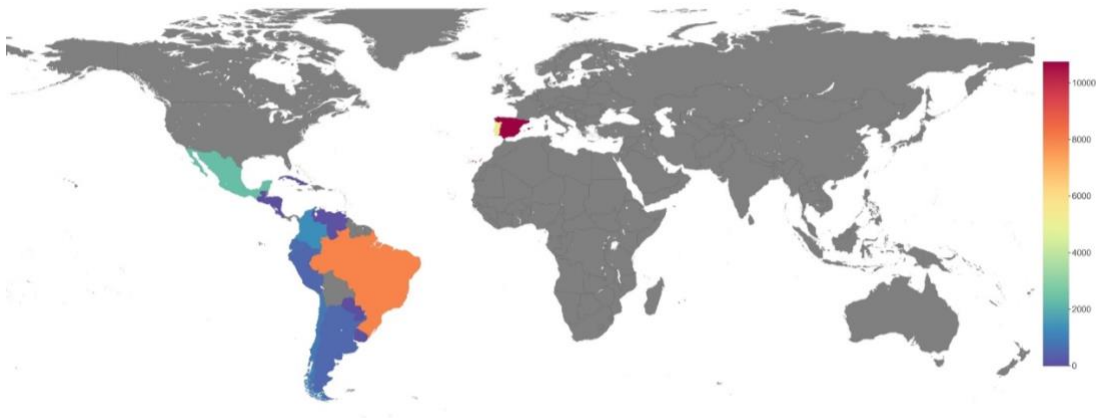

Figure 6. Contributions to the HCI domain in Ibero-America segmented by countries of the bloc.
Source: Created by the authors.

Given the above, the correlation between a country's economic development and its research output is evident in research on HCI in Ibero-America. Spain, Brazil, and Portugal, countries with high GDP, have the most publications in this field; this positive association suggests that economic prosperity allows for more significant investment in research efforts, fostering an environment conducive to studying HCI. Similarly, academic infrastructure may also be a determinant of research output, as evidenced by the prominence of countries with established university systems and ample research funding [31]. In contrast, countries with few publications, such as Honduras, Nicaragua, Paraguay, and El Salvador, may indicate limited research funding, fewer incentives for academic publication, or less developed higher education systems in these regions.

Finally, it should be noted that productivity in the domain in question is conditioned by the productivity of individual authors, which may result in the assignment of publications to one country or another, leading to an overall figure that exceeds the number of records collected in general in that field.

3.6 Collaboration between countries - world map

In the HCI domain in Ibero-America (Figure 7), we observe the existence of many research networks that are not limited exclusively to the Ibero-American region but extend globally, indicating the presence of intercontinental relationships in the countries of the bloc. This phenomenon is explained mainly by the participation of various established organizations and networks, such as the HCI-COLLAB Network [32], which is a collaborative organization that supports teaching-learning processes in the area of HCI at the Ibero-American level, or organizations that finance HCI projects in the region, such as the European Regional Development Fund (ERDF), which has sponsored more than 300 projects in this area, as well as other organizations such as the European Commission. These are examples of the various efforts of researchers to establish cooperation and research networks in this area at the Ibero-American and world levels.

Figure 7. Relations between countries in the Ibero-American and other international blocs.
Source: Created by the authors.

Analyzing the transnational relations between Ibero-American countries, Spain and the United Kingdom appear as the principal collaborators, with 237 shared documents. This suggests that language barriers do not hinder international relations and that geographical proximity may favor such connections. Spain collaborates significantly with the United States, as evidenced by the 190 documents shared. Germany and Italy follow closely behind, ranking third and fourth in terms of frequency of collaboration with Spain. In addition, Brazil and the United States have established 122 collaborative relationships. Within the Ibero-American bloc, Spain and Colombia have the highest level of collaboration, with 98 shared documents, consistent with the observation that the most productive authors in the Ibero-American region come from these countries.

In terms of specific countries, Argentina has collaborated mainly with France on 15 occasions, with Canada and Austria on 4 and 3, respectively. On the other hand, Brazil has the third highest number of scientific collaborations in this field and has collaborated most frequently with the United States on 122 occasions and with the United Kingdom on 69 occasions. It has also collaborated with Canada, France, Portugal, Germany, Japan, and Belgium on over ten occasions. Chile, for its part, has published mainly with Peru in the HCI domain, although countries such as France, Canada, Italy, the United Kingdom, Belgium, and Ecuador have also participated to a lesser extent. Finally, Colombia has collaborated mainly with Spain and Chile on 35 occasions. It has also collaborated with Saudi Arabia on 17 occasions, as well as with countries such as Canada, Costa Rica, Ecuador, France, and Mexico, to a lesser extent.

The analysis shows that research output in this field is concentrated in a few countries, such as Spain and Portugal; it also demonstrates patterns of collaboration probably driven by shared language, geographic proximity, and research networks.

3.7 Relationships between countries by authors

Focusing on analyzing the correspondence authorship of papers in the HCI domain in Ibero-America and their relationships (Figure 8), two categories of publications can be identified: those published in a Single Country Publication (SCP) and those published in collaboration with other countries. SCP indicates the number of papers published by each country within its borders, while Multiple Country publications (MCP) indicate the number of articles published by each country in collaboration with other countries [33].
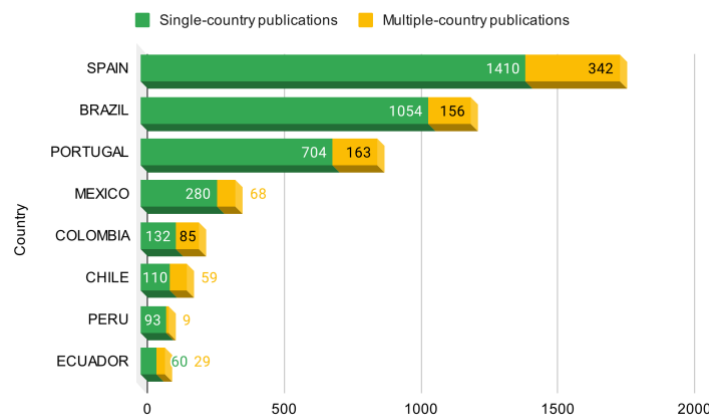

Figure 8. Documents segmented by single authors and authors from multiple countries.
Source: Created by the authors.

Among the most prominent countries in this domain, Spain has the highest number of single-country publications, with 1410, while multi-country publications account for 342. In terms of collaboration, Colombia has the highest percentage of publications in collaboration with other countries, with 39.4 % of its total publications. At the same time, Mexico and Spain also have a significant number of collaborative publications, representing approximately 19% of their total publications in both cases. In general, in all Ibero-American countries, there is a clear tendency to publish more in one country than in several.

As was previously mentioned, the percentages of authorship with authors from multiple countries are generally lower than those of exclusive national authorship. This contrasts with what has been reported in the literature, where it is indicated that international collaboration can be beneficial for the exchange of knowledge and resources, as well as for improving the quality and scope of research [34]. Therefore, this aspect could be the subject of further attention in this domain to strengthen this indicator further.

It is important to note that countries with a lower total number of publications, such as Peru, Ecuador, and Costa Rica, have a significantly higher proportion of publications from several countries than from a single country compared to countries with a higher number of publications, such as Spain and Brazil. This trend suggests that scientific collaboration through multinational authorship is more frequent among emerging research countries than among consolidated producers, which is aligned with a potential for growth in scientific production among countries with lower numbers of publications. Uruguay, Cuba, Venezuela, Paraguay, El Salvador, and Panama could benefit significantly from promoting international collaborations to improve their research productivity in the Ibero-American HCI domain.

In this sense, the observation that countries with a higher number of publications from a single country also tend to have more publications from several countries suggests that countries with more resources or a larger scientific community participate more actively in international collaborations.

3.8 Primary funding sources in the Ibero-American HCI domain

HCI research in Ibero-American (Figure 9) reveals multiple funding sources (96), indicating a broad spectrum of organizations contributing to advancing the field. In general, the distribution of sponsors shows an asymmetric pattern, with most sponsors supporting a small number of papers while a few supports the research output to a large extent. The largest sponsoring entity is Fundação para a Ciência e a Tecnologia, with 407 papers, followed closely by Conselho Nacional de Desenvolvimento Científico e Tecnológico, with 358 papers. The five main sponsors account for 57 % of the total production (not all papers have a sponsoring entity), which speaks of a concentrated support network but of significant impact.

Geographically, Spain, Portugal, and Brazil emerge as focal points, with multiple sponsoring entities, while European influence is evident through entities such as the European Regional Development Fund, European Commission, and Horizon 2020 Framework Programme. This diversified network of funding sources indicates the preponderance of specific sponsors but also underscores the variability in the number of papers across the spectrum, emphasizing the multifaceted nature of support in the dynamic landscape of HCI research in Ibero-America.
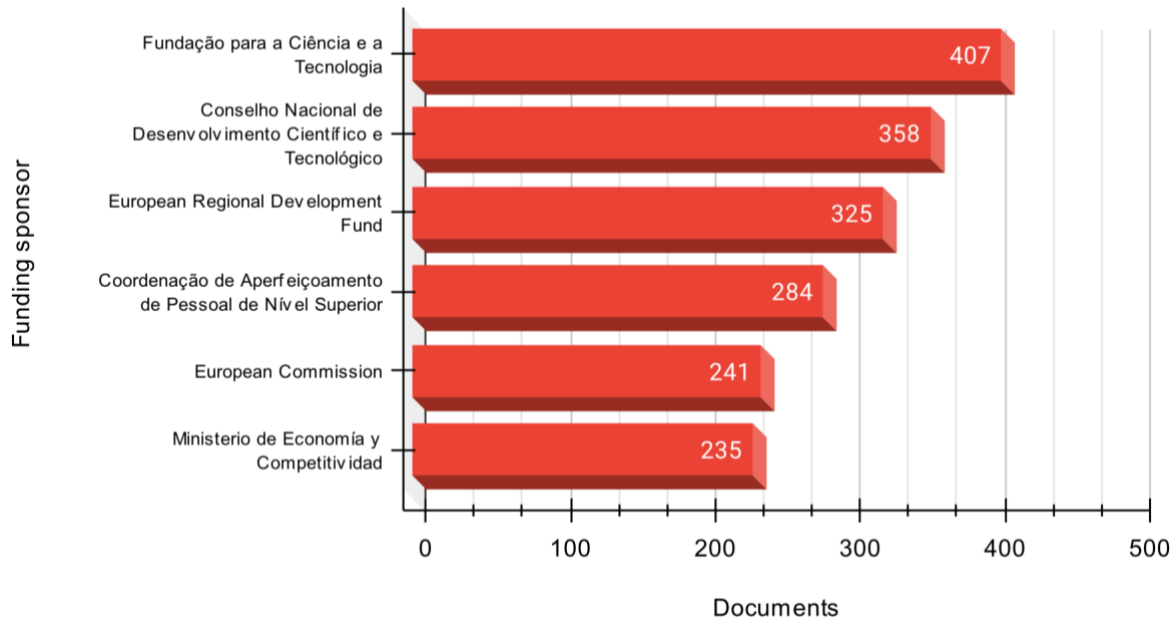
Figure 9. Main sponsoring entities in the Ibero-American HCI production domain.
Source: Created by the authors.

The scientific landscape of HCI research in Ibero-America shows patterns in the distribution of funding and collaboration in the domain. The Fundação para a Ciência e a Tecnologia emerges as the leading funder, underlining Portugal's strategic commitment to HCI research, as evidenced by its funding of 407 papers, a substantial advantage over the second funder. Brazil, represented by the Fundação para a Ciência e a Tecnologia, follows closely with 358 papers, another important player in the Ibero-American domain of HCI research. In particular, the strong presence of European entities, such as Fundação para a Ciência e a Tecnologia, underlines the critical role of Europe as a significant contributor to funding in the region, as discussed in the scientific literature [11]. In this line, it is essential to indicate that the sponsoring entities come not only from governmental entities but also from private technology companies, where Microsoft, Nvidia, IBM, and Google are represented [35]. However, in a much smaller percentage, this suggests an untapped potential for further funding from the private sector, which could catalyze further advances in Ibero-American HCI.

The distribution of funding also indicates that many sponsors support a small number of papers, suggesting a potential for more significant impact through more concentrated funding from a select group of sponsors. In addition, regional priorities and collaborative efforts are discernible from the concentration of sponsors within specific countries, highlighting the interconnectedness of funding and research in Ibero-America. The presence of global entities such as the European Commission and Horizon 2020 emphasizes the international collaboration and influence that shapes HCI research in the region.

3.9 Conceptual structure of the domain

The conceptual structure of a domain refers to the set of concepts, terms, relationships, and principles that define and describe a specific area of knowledge [36]. In this case, we sought to define the conceptual structure of the domain of HCI in Ibero-America using keywords of the authors in their respective documents and keywords plus, which are terms

used by databases to improve the indexing of documents in different classes [37]. When reviewing the analyzed documents and the authors' keywords (Figure 10), it was found that the word "Human Computer" appeared 907 times, while "usability" appeared 456 times. In addition, other relevant words were identified in the domain, such as "user experience", "virtual reality", "accessibility", "serious games" and "video games". This thematic diversity of the domain reflects the number of cross-cutting areas in which HCI is being worked in the region. It is also interesting that technologies such as virtual reality and accessibility, which are technologically dependent on other fields, contribute significantly to this domain. In parallel, keywords such as "usability" and "user experience" are also of great importance in this field and are the subject of numerous studies in HCI [38].

At a general level, keywords can be segmented into categories such as interaction technologies (virtual reality, augmented reality, mobile devices), interaction design methods (usability, user experience, user-centered design), computing fields (machine learning, artificial intelligence), and applications (education, serious games, video games), for the main words proposed by the authors in the domain.
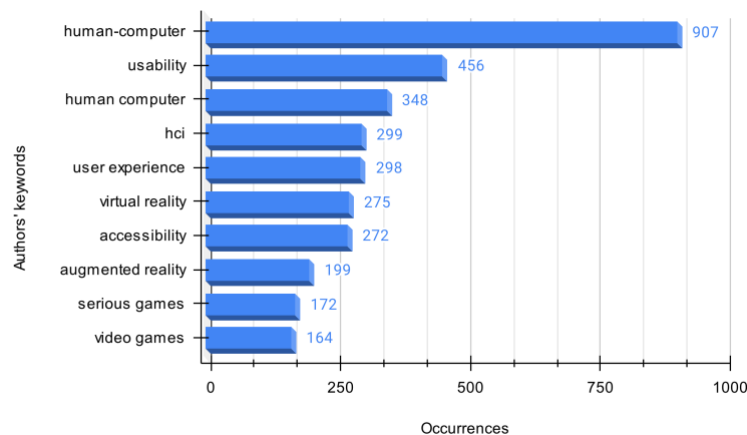

Figure 10. Keywords proposed by authors used in the HCI domain in Ibero-America.
Source: Created by the authors.

When analyzing the distribution of keywords within the Ibero-American HCI community, it becomes evident that "human-computer interaction" is the most frequent term, emphasizing its global importance in the field. Terms associated with specific technologies such as "virtual reality", "augmented reality" and "mobile devices" surpass the frequency of more general methodologies such as "interaction design" or "user-centered design", signaling the exploration of novel technologies over established design practices. The emphasis on interactive technologies for entertainment and learning, as indicated by keywords such as "video games," "serious games," "education," and "e-learning," speaks to the role of HCI in these point domains. Along these lines, terms such as "affective computing," "human-robot interaction," and "computer vision" suggest a dynamic research landscape with active exploration of emerging areas.

However, the decreasing frequency of terms such as "software engineering" and "human factors" implies a move away from traditional engineering-based approaches in favor of prioritizing user experience and design innovation. Also, there is a growing interest in immersive technologies, advanced computational approaches, and a user-centered design philosophy within the Ibero-American HCI community, which speaks of an interdisciplinary

nature is evident in keywords such as "gamification" and "assistive technology", indicating a broader scope that extends beyond the boundaries of conventional computing.
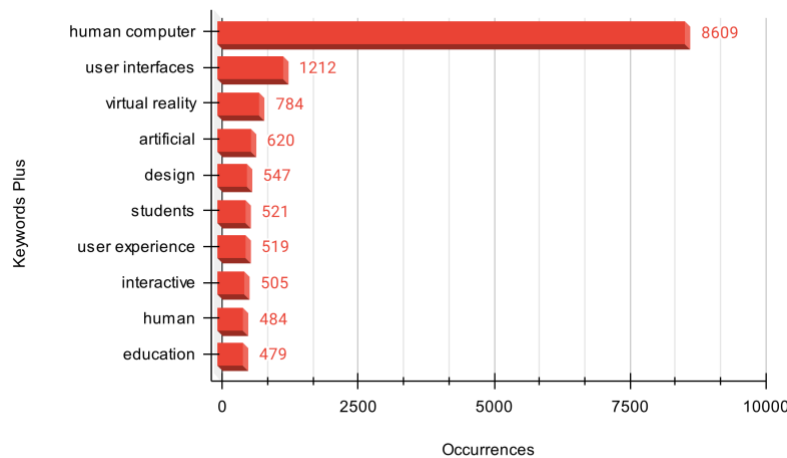

Figure 11. Keywords Plus used in the HCI domain in Ibero-America. Source: Created by the authors.

To the terminology used for keywords plus (Figure 11), it is observed that HCI occupies a predominant place with a total of 8609 occurrences, followed by user interfaces and virtual reality with 1212 and 784, respectively. Regarding of keywords plus, two significant items are students and education and have education as their primary focus, which may mean that the contributions in the domain are largely focused on developing tools for students or related to education [39].

3.10 Thematic evolution of the domain

The thematic segmentation of the domain considering its evolution can be analyzed from Figure 12, allowing us to understand the thematic structures over the years in the field. Specifically, from the 1990s to 2012, there was a greater focus on topics related to human-computer interaction, human-machine interaction, and human-robot interaction. Elements such as evaluation of these technologies and effective computing are also noted. From 2013 to 2016, the study and development of systems and devices capable of recognizing, interpreting, processing, and stimulating human emotions became more determinant, which is known as affective computing, which refers to trying to bring technological devices closer to their users. In the same period, interest in augmented reality also increased, which is in line with the presentation of technologies from companies such as Meta Platforms, Inc. or Google, LLC [40], which helps to democratize the use of technologies for ordinary users. In addition, semiotic engineering gained predominance in the domain, focusing on using early childhood devices [41].

From 2017 to 2019, increased attention was observed on specific HCI topics, such as usability and virtual communication, concrete and widely developed components within the traditional HCI framework. Likewise, Augmented Reality (AR) maintained its predominance, indicating its status as a reference technology for the Ibero-American community in human-computer interaction. This predilection is probably attributable to the advantages offered by AR, including better comprehension and longer-lasting knowledge retention [42]. Likewise, the expansion of AR is closely correlated with Natural User Interfaces (NUIs), aligning with the technological progression towards eliminating

controllers or input devices, thus promoting direct interaction with machines in the Ibero-American community [43]. On the other hand, video games have started to assume an essential role in Ibero-American HCI, with gamification in education as a benchmark [44]. Finally, there is a boom in artificial intelligence leading to the emergence of terms such as machine learning, which, although not traditionally applied, can be proposed in scenarios aimed at improving communication and human recognition of behavioral patterns.
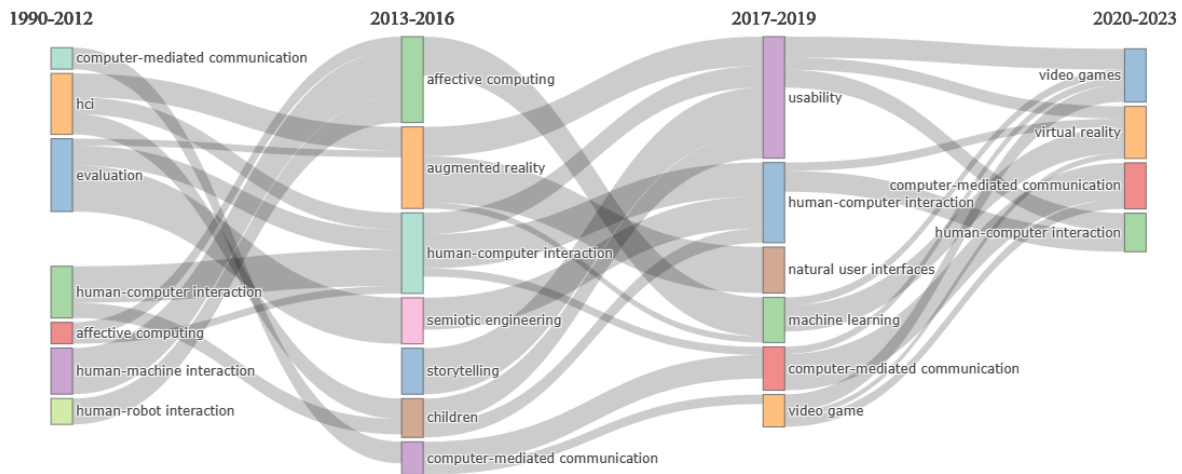

Figure 12. Thematic evolution of the Ibero-American HCI domain in a 33-year range of publications.
Source: Created by the authors.

Between 2020 and 2023, multiple recurring factors have been distinguished in the HCI literature. First, the domain of video games has undergone a significant evolution, mainly influenced by advances in machine learning and virtual reality technologies and typically employed in educational aspects [45]. Another fundamental element in the domain is virtual communication, which has materialized through different applications such as artificial intelligence [46] or eHealth systems [47]. In this line, it has also been observed that the topics are focused on improving the accessibility of people with disabilities from conceptual elements to primary developments, improving interaction with different digital devices [48]. In parallel, it is observed that the Ibero-American context is aligned with current trends documented in other studies on the evolution of HCI, with the priority being the improvement of vocal user interfaces, trying to make them more familiar and natural, allowing interaction in a more natural way instead of conventional input techniques [49]. Subsequently, a trend is observed in the domain to establish virtual and augmented reality as the primary tool to create more immersive and engaging user experiences, merging the physical and digital worlds [50]. Finally, wearable devices (smart watches, glasses, rings), which could provide users with more personalized and contextualized information and services, are an alternative trend [51].

Finally, HCI in the Ibero-American context has been recognized as a mature research field, with many distinguished scholars who have established the foundational principles of HCI and have significantly driven the progress of this discipline in alignment with contemporary global contexts. The thematic diversity observed in this field can be attributed to the broad network of researchers contributing to it and the evolutionary trajectory of the domain over time. Initially, the focus was on establishing the theoretical foundations of HCI, but it has since expanded its scope to encompass specific applications such as video games,

virtual reality, and wearable technology. Likewise, it is important to highlight that in the region, the challenges in HCI are similar to those in the rest of the world in terms of the rapid evolution towards more interactive and intelligent technologies, such as Artificial Intelligence, Big data, and the Internet of Things [52], so it is essential to address these challenges and emphasize cultural diversity in the design and evaluation of HCI [53]. Likewise, it is important to highlight that the establishment of a paradigm to explore how to create culturally sensitive and inclusive systems in the Ibero-American context, which are accepted and adopted by the community, would be a significant step toward the future of the domain, as reported in the literature [54].

3.11 Thematic map of the domain

A thematic map is a visual representation that reflects a specific area of study, illustrating the main themes derived from a co-occurrence analysis, allowing them to be classified into four distinct categories, namely, motor themes, niche themes, emerging or declining themes, and basic themes. These classifications are determined by their respective metrics of density and centrality [55]. Figure 13 presents the keywords extracted from the authors' in-domain keywords. These terms are represented in terms of their centrality and density within the cluster network. The term "centrality" denotes the importance of a topic in shaping a particular field of research. On the other hand, "density" indicates the extent to which a topic has been developed [56].

In the domain of HCI research in Ibero-America, the basic themes revolve around overriding themes that encapsulate the essence of the field. At its core, HCI serves as a frequent theme, providing the general framework upon which the entire research context is built. An essential concept in this part of the plane is usability, a critical aspect that analyzes the usability and efficiency of computer systems. Likewise, the positioning of virtual reality (VR) and augmented reality (AR) technologies as one of the most relevant specific technologies in the Ibero-American context, where researchers seek to take interaction to new dimensions, investigating the interface between humans and computer-generated environments or the augmentation of real-world experiences, as evidenced in research [57]. Another prominent theme is serious games, which focus on educational and training applications [58]. In this sense, machine learning and artificial intelligence appear as critical technologies beyond the boom of recent years, where the aim is to raise the quality of human-computer interactions, as reported [59]. Affective computing, focused on the recognition, interpretation, processing, and simulation of human emotions, adds a layer of emotional intelligence to the HCI spectrum, which is in line with multimodal interaction, which investigates the seamless integration of various modes of communication, such as touch, voice, and gestures, into the overall HCI experience [60].

Now, concerning the motor themes, higher education emerges as an essential point, emphasizing the exploration of interactive experiences within educational environments, underlining the commitment of the Ibero-American community to improve learning through the application of HCI principles [61]. In this line, collaborative learning represents another significant driving theme, being the preferred form of teaching methodology in the region and representing one of the maxims in this field, such as collaborative learning. These themes generally speak of a concerted effort to understand and optimize how individuals interact with computers in collaborative educational environments, reflecting a dedication to fostering compelling group learning experiences [62]. On the other hand, topics such as computer-mediated communication, networking, and social media continue to contribute to showing interest in leveraging HCI principles to utilize the potential of social technologies,

aligning with societal trends that prioritize digital connectivity and communication. Moreover, it shows how social networks can be transformed into platforms for excellent studies to understand the behavior of human beings in digital environments and other social contexts [63].
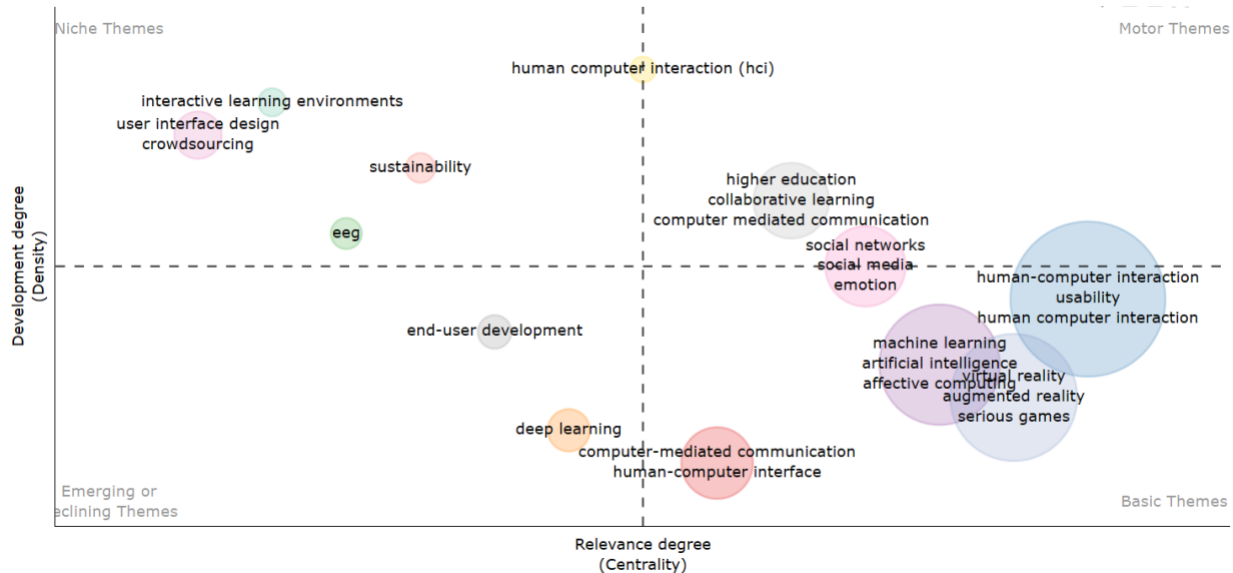

Figure 13. Thematic map of the HCI domain in Ibero-America. Source: Created by the authors.

In this line, it is essential to indicate that Facebook emerges as a favorite platform due to its prevalence of use in the region, reflecting the interest in understanding and optimizing interactions within platforms that have a significant weight in Ibero-American societies [64]. Similarly, another relevant driving theme is emotions, which speaks of how the Ibero-American research community gives importance to these psychophysiological reactions and is generally related to the design of interactive systems that consider and respond to affective factors that influence user experiences, showing a holistic perspective in HCI research [65].

Thematic niches emerge as foci of specialized exploration in the field of HCI research in Ibero-America; each delves into unique aspects of the field. In particular, the analysis of human gestures as input in HCI reflects a strong interest in understanding the details of nonverbal communication in digital interfaces, pushing the boundaries of traditional input methods, and indicating a perspective on the future of the field [62]. Interactive learning environments represent another thematic niche, focusing on the creation of tailored environments to foster interactive learning experiences, which aim to reshape the dynamics of learning [66]. Another prominent theme in this Cartesian plane is Crowdsourcing, which investigates the use of online groups to solve problems or contribute to projects, highlighting the collaborative nature of technology-driven solutions, bringing collective intelligence, and distributed problem-solving in the digital age [67]. Along these lines, the study of electroencephalogram (EEG) and brain signals in the context of HCI introduces a cutting-edge dimension, which could pave the way for applications such as neurofeedback or brain-controlled interfaces, reflecting a forward-looking approach to HCI, incorporating neuroscience advances into design and interaction paradigms, as reported [68]. Finally, occupational health, in the context of Ibero-American HCI, which focuses on the impact of computers on the well-being of people in the workplace, highlights the importance of considering the implications for health in the era of digitization.

Finally, regarding emerging or declining themes, the chart shows that artificial intelligence and robotics are undergoing continuous transformations, and that attention is being focused on this medium. In this regard, the rise of deep learning and neural networks implies a growing interest in advanced algorithmic techniques, which aligns with global advances in artificial intelligence and its application in multiple domains [69]. In parallel, the growing interest in human-robot interaction and medical robotics reflects a broader trend towards the integration of robotic systems in social and healthcare contexts, standing out as promising areas that are gaining ground, giving increasing importance to human-robot collaboration in various contexts, as reported in the literature [70].

3.12 Discussion

The bibliometric analysis performed in this research provides insights into the HCI research landscape in the Ibero-American region over the last three decades. In this sense, the results indicate a rapid growth in the production of publications in the domain, which highlights the growing relevance of HCI as an established research domain that addresses the sociocultural needs of Latin American and Iberian countries. This coincides with the growing ubiquity of digital technologies in society [71]. The conceptual diversity, which encompasses essential HCI elements such as usability and emerging technologies such as virtual reality, reflects the interdisciplinary maturity of the area. In this line, the conceptual structure of the field evolves, incorporating emerging technologies and domains such as artificial intelligence, machine learning, and affective computing, suggesting that HCI research in Ibero-America responds to regional demands and opportunities, as well as to global advances and standards in the field, as has been reported in other domains [72].

In this line, it is crucial to indicate that the concentration of research productivity in Brazil, Mexico, Portugal, and Spain may be related to the economic prosperity of these geographical areas, suggesting that the availability of funding and academic infrastructure are catalytic factors for research advances in the domain as reported in the literature [73], [74]. It was also observed that increased private-sector sponsorship could favor its expansion. Meanwhile, broad international collaboration favors exchanging ideas, but more robust regional networks could contribute to generating more contextual knowledge.

The results indicate that HCI research in Ibero-America receives funding from various sources, both public and private, national, and international. Something unexpected in the research concerns the relevance of European entities, rather than regional sources, in funding HCI research in Ibero-America. This points to the success of the European Union's policies in supporting research in developing countries [75]. In this sense, it is worth highlighting the position of Brazil in terms of the number of authors with a high publication rate, surpassing developed countries such as Spain, which accounts for the depth of research and interest in the area [76].

The main contribution of this study is to provide an overview of the current state and trends of HCI research in Ibero-America, identifying key players, issues, and challenges in the field and establishing a scholarly baseline of productivity patterns and collaborative networks in the region. This can serve as a platform for future research efforts on culturally informed HCI design paradigms targeting Ibero-American users. Finally, this analysis aligns with other work conducted in regions such as Scandinavia, thus contributing to the global contextualization of these results.

4.   CONCLUSIONS

In the present study, a bibliometric analysis was performed in the discipline of HCI at the Ibero-American level, without temporal limitations, using tools such as Bibliometrix and VOSviewer. A total of 9817 documents were examined, from which quantitative information was extracted covering a publication period from 1990 to 2023, emphasizing the primary authors, the countries of origin, and the structure of knowledge in the field. The main result of the research indicates that the Ibero-American community of HCI is a scientific leader in the world, addressing problems specific to the current context of the region. It was observed that the field presents an annual growth rate of publications of 14.6 %, which suggests that it is in constant evolution. In addition, consolidated research networks between different countries were identified, with Spain, Brazil, Portugal, and Mexico accounting for more than 90 % of the publications, indicating that the consolidated academic infrastructures of the countries probably contribute to more excellent research production in the field. The domain has a comprehensive collaboration network, both within and outside the region, indicating the presence of intercontinental relationships and the influence of global organizations and networks. Along these lines, in terms of types of publications, a diverse distribution of sources is observed, with a predominance of conference papers, suggesting a culture of knowledge sharing and rapid dissemination within the community.

In terms of funding sources, a broad spectrum of organizations contributing to the advancement of the Ibero-American discipline can be indicated, the main funders being the Fundação para a Ciência e a Tecnología and the Conselho Nacional de Desenvolvimento Científico e Tecnológico. In addition, it is noted that more significant sponsorship from the private sector could catalyze advances in HCI in Ibero-America. Regarding the main objectives, it seeks to ensure cultural sensitivity and inclusiveness in system design.

Now, in terms of the structure of knowledge in the domain, a deep conceptual richness is observed, ranging from the foundational concepts, terms, relationships, and principles that define and describe this area of knowledge to the use of emerging technologies such as virtual reality, artificial intelligence, and wearables. This reflects a mature and diverse discipline with a wide range of topics and applications that reflect the interdisciplinarity and societal impact of this discipline. The most frequent keywords are human-computer interaction, usability, user experience, virtual reality, augmented reality, serious games, and video games, highlighting the interest in immersive technologies, advanced computational approaches, and a user-centered design philosophy within the Ibero-American HCI community.

Future work from this research could be concerned with conducting similar bibliometric studies focused on specific sub-areas within HCI in Ibero-America, such as accessibility, virtual reality, and educational technologies, providing a deeper understanding of trends and research opportunities within the thematic niches. In terms of primary research, characterizing HCI researchers in Ibero-America to gain direct insight into the challenges, motivations, and perspectives on the state of HCI research in the region could enable the development of strategies and recommendations to increase HCI research activity and production in Ibero-American countries.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization, A.F.S.P., A.M., P.H.R., V.A.-D., and C.A.C.; methodology, A.F.S.P., A.M., P.H.R., and C.A.C software, A.F.S.P., V.A.-D., and V.A.-D.; validation, A V.A.-D..; formal analysis, A.F.S.P., A.M., P.H.R., and V.A.-D.; writing—review and editing, A.F.S.P., A.M., P.H.R., V.A.-D., and C.A.C. All authors have read and agreed to the published version of the manuscript.

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