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Bibliometric Analysis of Human-Centered AI in Education: Trends, Challenges, and Opportunities

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Abstract:

The addition of Human-Centered Artificial Intelligence (HCAI) in education presents equal opportunities and challenges, yet there is a lack of comprehensive understanding of how these technologies are being researched and implemented. This study conducts a bibliometric analysis to explore the trends, challenges, and opportunities associated with Human-Centered AI (HCAI) in education, focusing on research articles published in 2021. 233 articles were systematically selected from prominent academic databases, including IEEE Xplore, MDPI, Elsevier, ACM, and ARXIV. The selected articles were rigorously analyzed using VOSviewer and a bibliometric tool that facilitated the examination of co-authorship patterns and keyword trends within the dataset. The analysis revealed the diverse and interdisciplinary system of HCAI research, with significant contributions from leading academic publishers and a wide array of thematic focus areas and AI ethics, as well as student-centered learning and the integration of AI into educational systems. The findings indicate a growing collaborative effort among researchers across the globe, with certain authors and institutions emerging as key contributors to the field. These challenges highlight the critical gaps in current research, suggesting that future studies delve deeper into the long-term implications of HCAI in education and develop strategies to address the identified barriers. This research contributes to

the constant dissertations on HCAI by providing a detailed summary of the present national research and contribution and the potential future directions for scholars and practitioners in this field.

Keywords:

Bibliometric Analysis, Human Centered Ai, Education, Trends, Opportunities

Introduction:

In Human-centered AI (HCAI) is an approach to artificial intelligence progress and deployment that prioritizes human values, well-being, and proper thoughts in designing and using AI structures [1]. Traditional AI systems focus solely on achieving high-performance metrics and solving specific computational problems, while HCAI emphasizes the integration of human needs, desires, and limitations into AI technologies. This aims to create AI systems that are efficient and intelligent, aligned with human values, and consist of privacy, fairness, transparency, and user empowerment [2–3]. The status of HCAI deceptions lies in the latent connection between advanced technology and human experience. AI continues penetrating various sectors, including education, healthcare, and governance. Ensuring that these systems are developed with a human-centered approach is crucial to avoid the unintended consequences of bias, discrimination, and erosion of human autonomy [4]. HCAI seeks to empower users by giving them control over AI systems and ensuring that these technologies augment human capabilities rather than replace and undermine them. The focus on human-centered design principles and HCAI fosters trust, acceptance, and effective collaboration between humans and machines, making AI technologies more socially and ethically responsible [5].

In the education sector, the relevance of Human-Centered AI cannot be overstated. Education is a human-centric activity that aims to foster learning and personal development, gaining information and services [6]. Integrating AI into education offers numerous possibilities, modified knowledge capabilities, and bright training schemes and data for learner recitals. Without a human-centered approach, these AI applications can lead to challenges, including the risk of reinforcing biases, reducing the role of teachers, and compromising student's privacy [7]. HCAI in education aims to address these concerns by confirming that the AI system is designed to complement and enhance the educational experience rather than detract from it. AI-powered tools can be designed to support teachers by providing real-time feedback on

student progress and allowing for more personalized and adaptive instruction [8]. HCAI can help create AI systems that are transparent and explainable, allowing teachers and students to appreciate how the choices are finished and ensuring that AI recommendations are aligned with informative goals and morals.

The HCAI emphasizes the importance of inclusivity and accessibility in education, considering students' diverse needs and backgrounds. HCAI can contribute to the progress of Artificial Intelligence systems; these are more equitable and talented in addressing the requirements of all learners and those with disabilities and understated clusters [9]. This approach helps ensure that AI in education is a tool for empowerment and social good rather than exacerbating existing inequalities. The Bibliometric analysis is a valuable tool for understanding the evolution of research fields, identifying emerging trends, and mapping the intellectual structure of a specific domain [10-11]. In the setting of Human-Centered AI (HCAI) in education, conducting a bibliometric analysis consents scholars, educators, and politicians to increase a comprehensive view of the existing municipal of the field, including the key topics being explored and influential authors and prominent publications.

By analyzing research trends, scholars can identify gaps in the literature, assess the impact of various studies, and determine the direction in which the field is heading. This is particularly important in rapidly evolving areas like AI, where new technologies and methodologies are constantly being developed. These trends help predict future developments and inform research priorities and resource allocation decisions.

Here are the key research questions of this study listed below:

- What are these education systems' main human-centered AI (HCAI) research trends?
- Which publications, authors, and institutions have the most significant impact on the development of HCAI?
- What are the key challenges and opportunities in the current literature of the education sector?

The primary objectives of this learning are to conduct a comprehensive bibliometric examination of human-centered AI in education and focus on the research trends, challenges, and opportunities that have emerged in 2021. The study aims to achieve the following goals: Examine these trends' evolution over time and understand how they align with broader

developments in AI and education [12]. The study aims to analyze citation patterns and publication metrics and identify the most influential works, authors, and journals shaping the discourse around HCAI in education. This will provide insights into the key contributors to the field and the foundational literature that underpins current research.

2. Related Work

One of the significant trends in HCAI in education is the increasing use of AI-driven personalized learning systems. These systems analyze students' learning patterns, preferences, and performance data to tailor educational content and activities to individual needs. Research has shown that personalized learning can improve student engagement and achievement, particularly when combined with real-time feedback and adaptive learning pathways [12]. For example, AI-powered tutoring systems of intelligent tutoring systems (ITS) have been widely adopted in personalized instruction and practice to help students master complex subjects at their own pace [13].

Another emerging trend is using AI to enhance assessment and feedback mechanisms. Traditional assessment methods include the full range of student abilities and learning progress. HCAI offers the potential to develop more holistic and formative assessment tools that can evaluate cognitive skills and socio-emotional and creative competencies. AI-driven assessment tools can provide timely and detailed feedback to students and educators, enabling more effective interventions and support [14-15]. HCAI is increasingly being used to support collaborative and social learning. AI technologies can facilitate collaboration among students in adaptive learning groups, recommending peer mentors and providing tools for online communication and teamwork [16]. Research has highlighted the benefits of collaborative learning in fostering critical thinking, problem-solving, and communication skills (Dillenbourg, 1999). HCAI systems that support collaborative learning can create more interactive and engaging learning environments and promote deeper learning experiences.

2.1 Challenges in Implementing Human-Centered AI in Education

Despite the potential benefits, several challenges must be addressed to implement HCAI in education effectively. One of the primary challenges is ensuring data privacy and security. AI systems in education require large amounts of student data to function effectively. This raises concerns about the privacy and security of sensitive information and the potential for misuse or unauthorized access to data [17]. Ensuring AI systems comply with data protection

regulations and ethical standards is crucial to maintaining trust and safeguarding students' rights.

Another challenge is the risk of algorithmic bias and fairness. AI systems can inadvertently perpetuate or exacerbate existing biases in education and unfair outcomes for certain groups of students [18]. An AI system is trained on biased data to produce recommendations or decisions that disadvantage students based on race, gender, socioeconomic status, or other factors [19-20]. Address bias in AI, considering the data used for training to ongoing treatment and evaluation to ensure fairness and equity in educational outcomes. The integration of HCAI in education also poses challenges related to the role of educators [21-22]. While AI technologies can augment and support teaching, they should not replace the essential human elements of education for fostering meaningful relationships, empathy, and motivation. Educators must be empowered to use AI tools, and adequate training and support must be provided to understand how these technologies can complement their teaching practices [23]. There is a need to balance the automation of certain educational tasks and the preservation of the human touch in education.

2.3 Opportunities for Advancing Human-Centered AI in Education

There are numerous opportunities to advance HCAI in education. One of the key opportunities lies in developing AI systems co-designed with educators and learners [24]. Involving stakeholders in the design and development process ensures that AI tools are aligned with the needs and values [25-26]. Co-design approaches can lead to more user-friendly and effective AI systems better integrated into educational practices [27]. Another opportunity is the potential for HCAI to promote inclusivity and accessibility in education. AI technologies can be leveraged to create adaptive learning environments that accommodate diverse learning styles, abilities, and needs. AI-driven assistive technologies can support students with disabilities by providing customized learning resources with speech recognition accessibility features [28]. HCAI can help bridge educational gaps so all students have equal opportunities to succeed. HCAI offers the potential to foster lifelong learning and professional development through AI-powered learning platforms, personalized learning paths for individuals at different stages of their careers, continuous skill development, and knowledge acquisition [29]. As work evolves, there is a growing demand for flexible and adaptable learning solutions that can support reskilling and upskilling throughout a person's life [30]. HCAI can create these opportunities to empower individuals to take control of their learning journeys.

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3. Methodology

In this research, we collected the 233 article data for 2021 from different sources and organized and prepared the raw data in Excel. The next step is the inclusion and exclusion of ready data for analysis [31]. Use the Vosviewer tool for bibliometric analysis, in which we use the co-authorship analysis of our 228 articles to explore the HCAI trends and challenges in the education sector; the proposed framework is given below in Figure 1:

Figure 1: Proposed framework

2.1 Collection of Databases

The comprehensive data collection process was underfed, focusing on many theoretical files to confirm extensive attention to pertinent works. The databases for this bibliometric analysis include IEEE Xplore and Semantic Scholar plus Elsevier (including ScienceDirect) and Google Scholar plus Scopus and DirectScience. These databases were selected based on their extensive collections of peer-reviewed articles, conference papers, and other scholarly works related to Human-Centered AI (HCAI) and education [32]. The study aims to capture a broad spectrum of research outputs and ensure that established and emerging field trends are well-represented by leveraging a large set of databases.

2.2 Search Strategy and Keywords

A well-defined search strategy below Table 1 was employed to systematically retrieve relevant literature from the selected databases [33]. The search process involved using a mixture of keywords and Boolean operators to filter results effectively.

Table 1: Search Strategy Keywords

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Database	Primary Keywords	Secondary Keywords	Filters Applied
IEEE Xplore	"Human-Centered AI," "Education," "AI in Education"	"Pedagogy," "Student-Centered Learning," "AI Ethics"	Publication Year: up to 2021, Document Type: Articles, Language: English
Semantic Scholar	"Human-Centric AI," "Educational Technology," "AI Learning"	"Personalized Learning," "Ethical AI," "Educational AI Systems"	Publication Year: up to 2021, Document Type: Articles, Language: English
Elsevier (ScienceDirect)	"Human-Centered AI," "AI in Education," "Learning AI"	"Ethical AI," "Educational Technologies," "AI and Pedagogy"	Publication Year: up to 2021, Document Type: Articles, Language: English
Google Scholar	"Human-Centered AI," "Education," "Ethical AI"	"Student-Centered Learning," "AI Ethics," "Personalized Learning"	Publication Year: up to 2021, Document Type: Articles, Language: English
Scopus	"Human-Centered AI," "AI in Education," "Learning Technologies"	"AI and Pedagogy," "Ethical AI in Education," "Personalized AI"	Publication Year: up to 2021, Document Type: Articles, Language: English
DirectScience	"Human-centered AI," "Educational AI," "AI and Learning"	"AI Ethics," "Student-Centered AI," "Educational Technologies"	Publication Year: up to 2021, Document Type: Articles, Language: English

2.3 Bibliometric Tools

VOSviewer is a sophisticated yet user-friendly software tool designed primarily for constructing and visualizing bibliometric networks, making it indispensable in academic

research contexts. Its capabilities extend beyond mere visualization and offer robust analytical tools to explore complex relationships within large datasets derived from scholarly literature [34]. At its core, VOSviewer excels in transforming textual data into insightful visual representations that are co-occurrence information to map out intricate networks of authors' keywords and publications. This process enables researchers to uncover hidden patterns, thematic clusters, and emerging trends that are pivotal in understanding the evolution of scientific knowledge and scholarly communication [35].

Here are some key features of this tool:

- **Network Visualization:** VOSviewer visualizes networks where nodes represent entities (like authors or keywords), and edges represent relationships (like co-occurrence or co-authorship).
- **Clustering:** It identifies network clusters based on similarities and helps visually group related entities.
- **Density Maps:** It provides density maps that highlight areas of higher concentration within networks and aid in identifying key clusters or trends.
- **Keyword Co-occurrence Analysis:** This is particularly useful in analyzing literature, as it can visualize which keywords appear together and indicate thematic connections.
- **Customization:** Users can customize visualizations by adjusting colors, sizes, and layouts to enhance clarity.
- **Data Import:** Supports various data formats, including bibliographic data from sources like Scopus and Web of Science, plus direct imports from files.

Why VOSviewer is Chosen for Studies:

- **Ease of Use:** Propose a user-responsive edge and make it reachable even to researchers without extensive programming skills.
- **Comprehensive Visualization:** It provides comprehensive visual summaries of complex datasets, making identifying trends, clusters, and relationships easier.
- **Analytical Capabilities:** Beyond visualization, it offers analytical tools and clustering density maps, enhancing the depth of analysis.

- **Widespread Adoption:** It is widely recognized and used in academic circles, ensuring compatibility with existing literature and research practices.

- **Free Availability:** It is freely available for non-commercial use and is accessible to researchers across different institutions and disciplines.

VOSviewer stands out for its robust visualization capabilities and analytical tools, which make it a preferred choice for visualizing and analyzing bibliometric data in various research studies.

2.3 Data Analysis

After collecting a total of 233 articles from various academic databases (IEEE Xplore, Semantic Scholar, and Elsevier plus Google Scholar Scopus and DirectScience), the next step involved refining the dataset to certify that single pertinent then first-class readings were comprised in the bibliometric analysis [36]. The standards for inclusion and exclusion were established to maintain the focus on human-centered AI (HCAI) in education and filter out irrelevant and redundant studies.

Inclusion Criteria:

- **Relevance to HCAI in Education:** Articles must explicitly address the application, challenges, and opportunities of HCAI in educational settings.
- **Publication Year:** Only articles published in 2021 were included to ensure the analysis reflects current trends.
- **Peer-Reviewed Sources:** Only peer-reviewed articles, conference papers, and reviews were considered to ensure the credibility and academic rigor of the included studies.
- **Language:** Only articles written in English were included to maintain consistency and ensure accessibility.

Exclusion Criteria:

- **Irrelevant Topics:** Articles that did not focus on HCAI and its application in education were excluded.
- **Duplicate Records:** Duplicate entries in the different databases were identified and removed to avoid skewing the analysis.

- **Non-Primary Research:** Editorials, opinion pieces, and non-peer-reviewed articles were excluded as they do not provide empirical data and substantial contributions to the field. This inclusion/exclusion process resulted in a curated, relevant, manageable dataset that lays the groundwork for a meaningful bibliometric analysis [37].

- **Metrics Used for Analysis:** The refined dataset was then analyzed using VOSviewer and a bibliometric tool known for its ability to visualize and interpret complex bibliometric data. The analysis focused on several key metrics to explore the trends and challenges associated with HCAI in education:

- **Co-Authorship Analysis:** This metric was used to examine the collaborative relationships between the authors in the field of HCAI in education; the analysis of co-authorship patterns and the study aimed to identify prominent researchers, collaborative networks, and influential institutions contributing to the development of HCAI in education. This analysis also helped us understand the geographical distribution of research efforts and the level of international collaboration in the field [38].

These metrics, when combined, offer an inclusive summary of the study trends, challenges, and opportunities in the field of Human-Centered AI in education, as revealed through the bibliometric analysis of the 233 selected articles.

4. Analysis and Results

In recent centuries, the exploration system in human-centered AI (HCAI) has witnessed significant growth and is characterized by an increasing number of publications across various academic outlets [39]. This section provides a complete investigation of the publication trends and identifies key authors' influential papers and collaboration networks within the HCAI research community from Figure 2. The examining annual publication trends and distribution with publication type and co-authorship patterns and analysis highlights the evolution of research contributions and the global collaborative efforts shaping the field.

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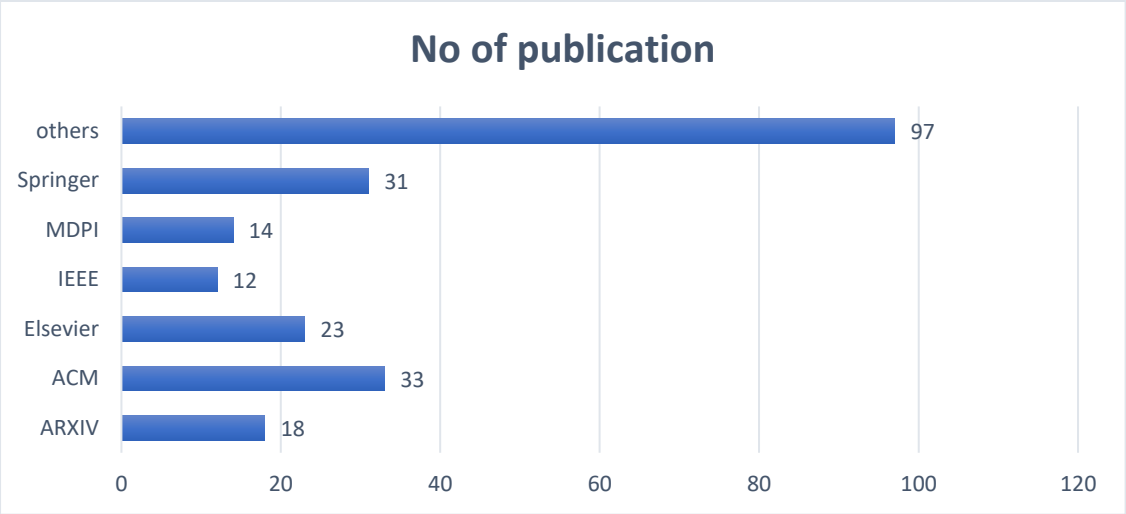

Figure 2:No of publications in 2021

The distribution of publications with various publishers in the HCAI research domain shows a large system. The ACM leads with 33 publications, followed closely by Springer with 31 and Elsevier with 23. ARXIV MDPI and IEEE contribute with 18, 14, and 12 publications, respectively. A significant portion of 97 publications is attributed to other smaller and less frequently mentioned publishers, which indicates a broad dissemination of research across different platforms and reflects the interdisciplinary nature of HCAI studies.

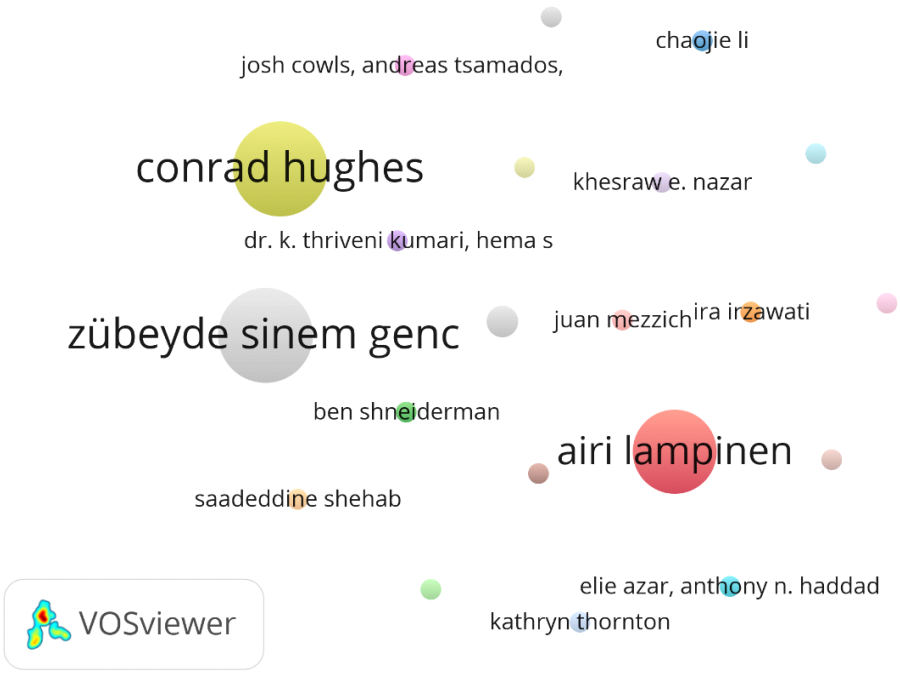

Figure 3: Co-Authorship Network Graph

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The co-authorship network visualization above Figure 3 from VOSviewer depicts the collaboration patterns among authors in 228 paper datasets on Human-Centered AI in Education. The size of each node represents the number of papers associated with the writer, and higher lumps represent more prolific authors in the dataset [40]. The nodes' proximity reproduces the collaboration's asset amid authors and closer nodes representing more frequent co-authorship. Authors like Conrad Hughes and "Airi Lampinen" have larger nodes, suggesting they have contributed significantly to the body of work, while the color-coded clusters indicate groups of authors who collaborate. There was "Zübeyde Sinem Genc," which appears to be part of a separate cluster and possibly working with different co-authors to highlight the distinct research focus and geographical collaboration pattern. "Airi Lampinen" is part of another cluster and indicates another collaboration network within the field [41]. The spatial arrangement of the nodes shows the strength of the co-authorship ties of authors positioned closer to each other. For example, "Josh Cowls and Andreas Tsamados" have stronger co-authorship relationships and signify more frequent collaborations.

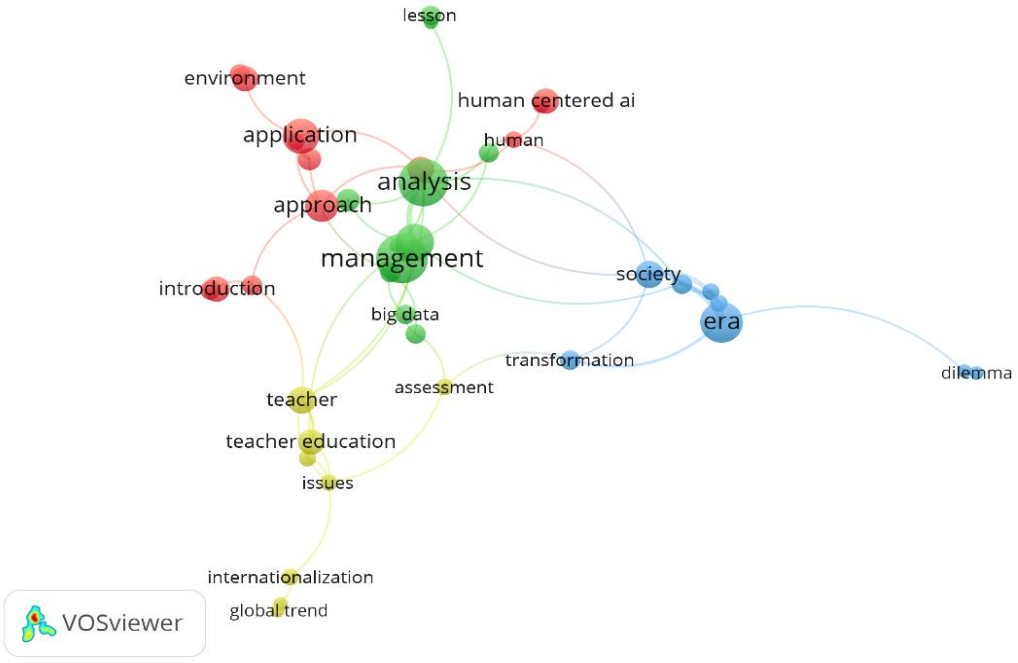

Figure 4: Title and keywords-based graph Analysis

The network visualization of key terms is extracted in Figure 4 from the titles and abstracts of 233 research papers. The nodes representing frequently occurring terms are clustered into

different colors, which indicate distinct thematic groups. This green cluster focuses on terms related to "management," "analysis," and "big data." It suggests that most research emphasizes the analytical and managerial aspects of human-centered AI (HCAI) and data-driven result creation [42]. The red cluster is centered around terms like "application," "approach," and "environment." This indicates a focus on practical applications and methodological approaches in various environments and possibly exploring the integration of HCAI into different contexts. Yellow terms like "teacher education," "issues," and "global trend" are highlighted in this cluster, suggesting a focus on the educational aspects of HCAI and particularly how global trends and issues impact the field. The blue cluster is more isolated and focuses on terms like "era," "society," and "transformation," pointing to discussions around the societal impact and the transformative era of HCAI and possibly reflecting on ethical then, cultural, and societal shifts due to AI [43].

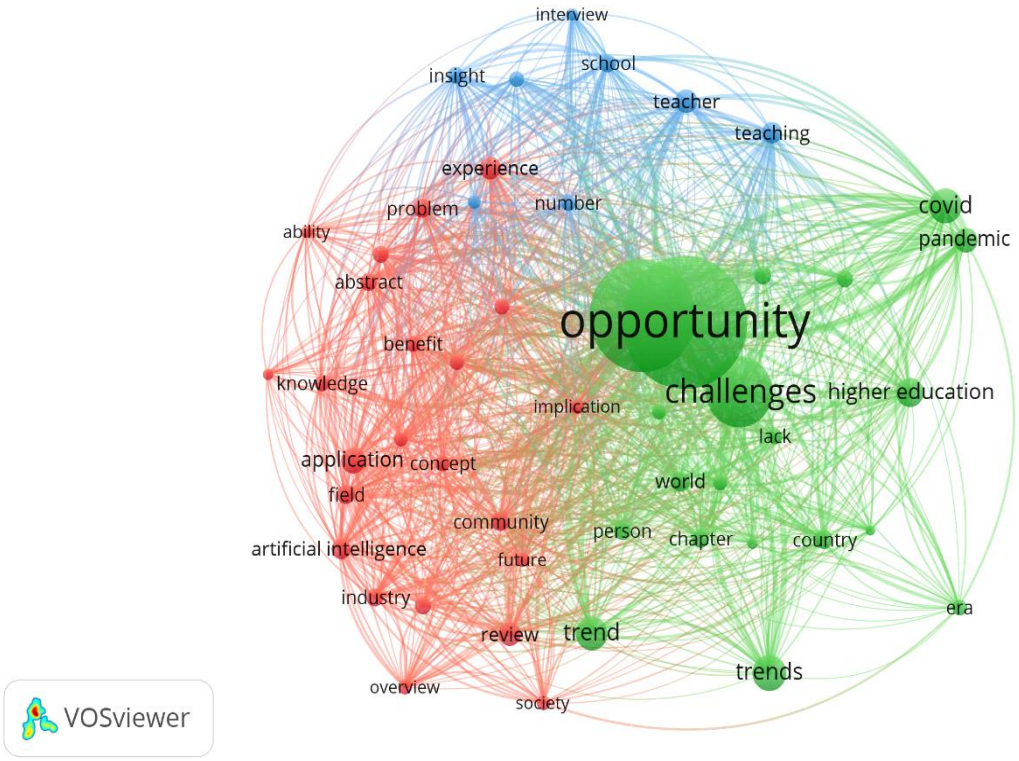

Figure 5: Visualization of Network Title and Abstracts

The above complex network visualization from Figure 5 depicts the co-occurrence of terms in the abstracts of 233 research papers in 2021. The largest cluster is green in this image, which centers around the terms "opportunity," "challenges," and "higher education." This indicates

that a significant body of research is attentive to exploring the opportunities and challenges HCAI presents within the context of higher education and the global implications of these trends [44]. The red cluster is dense with terms like "application" and "concept," then "artificial intelligence" and "industry." This cluster likely represents intensive research on the claim of artificial intelligence in industry and examines the different concepts and the practical use of AI technologies in various sectors. This cluster blue highlights terms such as "insight," "experience," and "problem." It appears to represent a more reflective or evaluative aspect of the research, possibly focusing on what has been gained from real-world experiences with HCAI and addressing the problems and challenges encountered [45].

5. Discussion

5.1. Keys Finding and Trends in HCAI Research In Education

The bibliometric analysis of 233 articles on Human-Centered AI (HCAI) in education from 2021 highlights several key trends in the research system. The field has seen substantial growth with many publications on various academic platforms. The analysis shows that a significant portion of the research is disseminated through prominent publishers like ACM Springer and Elsevier, underscoring their pivotal role in the distribution of HCAI research. The broad dissemination of research across many smaller publishers also reflects the interdisciplinary nature of HCAI studies, and contributions are made from fields like computer science, education, and ethics.

The co-authorship analysis further illustrates the collaborative nature of research in this domain. Key authors Conrad Hughes and Airi Lampinen then emerged as central figures in the research community and contributed significantly to the body of work. The analysis of co-authorship patterns also highlights the existence of distinct research clusters and indicates focused collaboration networks.

5.2. Challenges in HCAI Implementation

- The execution of HCAI in tutoring presents several challenges and is tinted in the literature. One major challenge is adding AI technologies to the existing instructive frameworks [14].

- The co-occurrence of terms like "challenges," "higher education," and "global trend" suggests that researchers are grappling with the complexities of adapting AI to the specific needs of educational institutions.

- Another significant barrier is insufficient infrastructure and resources, especially in lower-income regions.

- The clustering of terms around "application," "concept," and "industry" indicates that while there is substantial interest in applying AI within educational contexts, there are also considerable hurdles in translating these concepts into practice [15].

- These challenges include aligning AI with educational goals, addressing ethical concerns, and ensuring equitable access to AI-driven tools.

5.3. Opportunities for Future Research

These challenges and the analysis are also significant opportunities for future research in HCAI. The gaps identified in the current research system highlight the need for more interdisciplinary studies that bridge the gap between AI technology and educational theory. There is considerable research on the technical aspects of AI, and there is little focus on how these technologies can be effectively integrated into pedagogical practices [16]. Future research should also explore the long-term impacts of HCAI on educational outcomes. This includes examining how AI-driven tools influence not just academic performance but also social and emotional learning; there is a need for studies that address the ethical and societal implications of HCAI concerning issues of equity and access.

6. Conclusion

The bibliometric analysis shown in the reading offers a complete indication of the current landscape of Human-Centered AI (HCAI) research within the education sector and is based on examining 233 articles published in 2021. The findings are increasing attention to integrating AI skills in educational settings, with significant contributions from diverse academic sources. The analysis of co-authorship patterns and keyword trends highlights the collaborative nature of this research field, the thematic focus areas of AI ethics and student-centered learning, and the transformative impact of AI on education. The challenges of ethical considerations, the complexity of AI implementation, and the need for personalized learning solutions remain prominent barriers to the broader adoption of HCAI in education. These challenges also point

to critical breaches in the present inquiry and feature the inevitability of impending revisions to report these concerns, explore the long-term implications of HCAI, and develop strategies for overcoming the barriers identified. This study underscores the importance of continued research in HCAI to realize its potential in enhancing educational outcomes and ensuring ethical and equitable AI integration in learning environments.

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