Trends in Artificial Intelligence for Autism Spectrum Disorder: A Bibliometric Analysis Study

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Trends in Artificial Intelligence for Autism Spectrum Disorder: A Bibliometric Analysis Study

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Abstract

This study aims to analyze the bibliometric trends of research articles on applying Artificial Intelligence (AI) technology in individuals with Autism Spectrum Disorder (ASD). Within the scope of this study, bibliometric data from 1345 articles published in the Web of Science database between 2014 and 2024 were examined. The analysis revealed a significant increase in studies on using AI technology in the diagnosis and educational processes of individuals with ASD since 2018. The findings indicate that the United States (USA), China, and India are the leading contributors in terms of publication volume in this field. Additionally, the most frequently used keywords in these publications include "ASD," "Machine Learning," and "Deep Learning." In addition, the notable contributions of researchers such as Dennis Wall, Peter Washington, and Aaron Kline have drawn attention. This study highlights the potential of AI technologies in facilitating accurate and rapid diagnosis of ASD and in enhancing personalized educational processes. Moreover, it provides a foundation for future research by identifying key trends in the literature.

Introduction

The rapid development of information and communication technologies and their integration into almost every field have made the role of educational technologies in education more valuable than ever. Today, as children begin using modern technologies at an early age, they do not feel unfamiliar with the educational technologies they encounter when they start school and may prefer learning environments developed with these technologies over traditional methods (Andreyeva et al., 2019; Çalışkan, 2021; Stanojević et al., 2018). In addition to providing engaging, attention-grabbing, and motivating content for students, these learning environments enable learners to have flexible learning experiences at their own pace, independent of time, location, and instructors (Arslan et al., 2022; Petko et al., 2017; Trust, 2018). The potential of these learning environments, particularly in addressing the learning needs of individuals with special educational needs, is substantial (Kavan, 2021; Olakanmi et al., 2020). Accelerating the diagnosis process of individuals with special needs, facilitating their learning processes, and improving their quality are considered among the most critical challenges in educational environments. In the literature, individuals with special needs are categorized into different groups, including learning disabilities, attention deficit hyperactivity disorder (ADHD), intellectual disabilities, language, speech, and communication disorders, and autism spectrum disorder (ASD) (Odabaşı, 2021; Special Education Services Regulation, SESR,

2018). Among these categories, ASD is one of the most prominent groups (Kalemkuş, 2024; Sağdiç and Sani-Bozkurt, 2020). In this context, individuals with ASD were included in the scope of this study. ASD is a neurodevelopmental disorder characterized by significant difficulties in fundamental life skills, such as social interaction, communication, and restricted interests (American Psychological Association, APA, 2013).

According to SESR (2018), individuals with ASD are classified into three categories: mild, moderate, and severe. Since the types, degrees, and characteristics of these individuals' differences vary, both learning environments and environments used for diagnostic purposes need to be customized to meet their specific needs. Therefore, when designing these environments for individuals with ASD, it is crucial to develop technology-supported environments instead of relying on traditional methods (Diken, 2012; Haleem et al., 2022). One of the key technologies utilized in designing learning environments for individuals with ASD is AI technology. According to the Horizon reports published in recent years, AI technology is expected to have a significant impact on education soon. The Horizon reports published in 2021 highlighted that the integration of AI into education could yield substantial benefits within a few years. Mıhcı and Gezgin (2023) suggest that AI in special education holds significant potential for personalized learning, assistive technologies, and behavior monitoring. Analyzing the literature on AI applications in special education reveals that most of the developed applications are designed specifically for students with ASD (Sağdiç and Sani-Bozkurt, 2020).

AI technology, which is widely used in the diagnostic processes of individuals with ASD, facilitates the rapid identification of these individuals and the implementation of necessary interventions (Arthi & Tamilarasi, 2008; Wall et al., 2012; Kosmicki et al., 2015; Duda et al., 2016; Rad & Furtanello, 2016; Del Coco et al., 2017; Mujeeb et al., 2017; Yuan et al., 2017; Li et al., 2018; Goel et al., 2020; Küpper, 2020; Cao et al., 2021; Itani & Thanou, 2021; Negin et al., 2021; Kashef, 2022; Abbas et al., 2023; Paolucci et al., 2023; Parui et al., 2023). In a study conducted by Kosmicki et al. (2015) aimed at diagnosing individuals with ASD, a machine learning algorithm was developed based on selected items from the Autism Diagnostic Observation Schedule (ADOS). According to the research findings, the designed system was able to screen for ASD with 98% sensitivity and 89% specificity. These results indicate that machine learning-based systems hold promising potential in the screening and detection processes of ASD. Yuan et al. (2017) developed a chatbot based on natural language processing technology for ASD diagnosis. This system analyzes text-based responses from users, identifies keywords, and derives meanings from these words. The chatbot, which constructs a decision tree based on the extracted meanings, predicts the user's ASD severity level. When compared to diagnoses made by psychologists, the chatbot demonstrated effective performance in ASD diagnosis with an accuracy rate of 88%, suggesting that it could be a valuable tool in ASD assessment.

Daniels and Wall (2016) developed a mobile autism risk assessment application (MARA) for families. This application consists of a seven-item survey presented on a digital platform and can be completed in approximately five minutes. In the survey, each question offers four to five response options, and participants' answers are processed using a decision tree algorithm powered by a machine learning model. Based on the collected data, the application provides families with results regarding ASD risk. According to the research findings, the application distinguished ASD from other developmental disorders with an accuracy rate of 89%, demonstrating its strong

potential as a diagnostic tool.

AI is one of the technologies utilized in teaching processes, although it is not as extensively used for diagnosing individuals with ASD. Srinivasan and Parthasarathi (2013) aimed to support teachers by transforming complex skills into skill analyses using an AI-supported tool they designed. In a study conducted by Marinoiu et al. (2018), 3D data of students with ASD undergoing robot-assisted therapy were analyzed using multiple approaches for movement and emotion recognition. Similarly, Amiri et al. (2017) designed an AI-based smartwatch that detects and records the motor stereotypic movements of children with ASD. The findings indicated that these devices could serve as a valuable support tool for therapists in the future, as the smartwatch accurately measured the stereotypic movements of children with ASD with a sensitivity of 94.6%.

In another study, Riedl et al. (2009) integrated AI into social stories designed for high-functioning individuals with ASD. The study involved designing scenarios that simulated real-life situations individuals might encounter in social environments, such as movie theaters. In each scenario, participants were presented with two or more action options, and based on the action selected, the system dynamically generated new situations and continued to present choices. The study concluded that such systems offer several advantages over traditional social skills interventions, including incorporating social variables, being interaction-oriented, providing experiences more closely aligned with real-life scenarios, delivering consistent feedback, and supporting generalization.

The strong emphasis on the relationship between AI and ASD in the literature demonstrates that these technologies are becoming increasingly significant for individuals with ASD and continue to be a prominent subject of study. In this context, the aim of this study is to analyze the literature on the use of AI applications for individuals with ASD, present the current state of research, identify general trends and gaps in the field, assist academics in understanding key issues related to AI use in individuals with ASD and generating new ideas, and discuss the implications and future directions of AI applications in this area. It is believed that this study, conducted in line with this objective, will not only contribute to the advancement of scientific knowledge but also serve as a guide for transforming educational processes. In this bibliometric analysis study, the following research questions were addressed:

1. How many publications on AI applications for individuals with ASD have been produced in the last 10 years?
2. Which journals have published the most research on AI applications for individuals with ASD?
3. Which keywords have been most frequently used in publications on AI applications for individuals with ASD?
4. Which countries/regions, institutions, and authors have been the most productive in publishing research on AI applications for individuals with ASD?
    - What is the distribution of publications by country?
    - What is the distribution of publications by authors?
    - What is the author co-citation network?
    - What is the co-authorship network according to the institutions/universities to which the authors are affiliated?

• What is the co-authorship network based on the region/country?

Method

In this study, the WoS database was utilized because it provides easy access to databases and citation data (Karasozen et al., 2011) and is one of the most widely used academic databases (Albas, 2023). The research was conducted using the bibliometric analysis method. The bibliometric analysis method involves the application of statistical and quantitative analysis techniques to identify the general characteristics of studies published in a specific field or on a particular subject (Pritchard, 1969). This method enables the visualization of research trends by offering a broad perspective on the existing literature.

Data Collection

The bibliometric data examined in this study were obtained from the WoS database, which includes more than 20,000 journals and includes data from 1945 to the present. The reasons for conducting the analysis in the WoS database include the fact that it includes indexes such as Science Citation Index (SCI), Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) and Arts & Humanities Citation Index (A&HCI), which are accepted as respected citation indexes by academic circles, and that it allows scanning a wide range of literature.

Information regarding the keywords used to access relevant studies within the scope of this research is presented in Table 1.

Table 1. Keywords Used for Queries in WoS Database

ASD Terms		AI Terms	
Autism Spectrum Disorder		Artificial Intelligence	
Autism		Machine Learning	
OR ASD	**AND**	Neural Networks	**OR**
Early Detection		Deep Learning	
Diagnosis		Assistive Technology	
Social Skills Training		Natural Language Processing	

WoS Query text: "Autism Spectrum Disorder" AND "Artificial Intelligence" or "Autism Spectrum Disorder" AND "Machine Learning" or "Autism Spectrum Disorder" AND "Deep Learning" or "Autism Spectrum Disorder" AND "Neural Networks" or "Autism Spectrum Disorder" AND "Natural Language Processing" or "Autism Spectrum Disorder" AND "Early Detection" AND "Artificial Intelligence" or "Autism Spectrum Disorder" AND "Diagnosis" AND "Machine Learning" or "Autism Spectrum Disorder" AND "Intervention" AND "Deep Learning" or "Autism" AND "Artificial Intelligence" AND "Social Skills Training" or "ASD" AND "Assistive Technology" AND "Artificial Intelligence".

The selection process of studies included in this research is presented in Figure 1, following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram (Liberati et al., 2009). The PRISMA flow diagram provides a structured representation of how the analysis was conducted. Studies were included in this research if they met the following criteria: they were published as journal articles, appeared between 2014 and 2024, and were written in English.

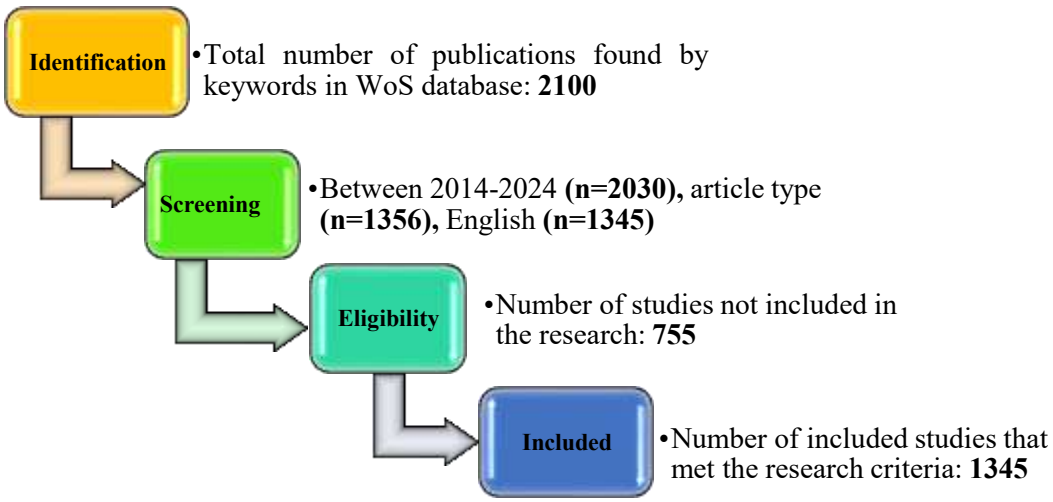

Figure 1. PRISMA Flow Diagram

Data Analysis

The bibliometric data of 1345 studies examined within the scope of this research were analyzed using the VOSviewer software. This program, developed by Van Eck and Waltman (2010), is a free tool that enables the creation of both numerical and visual maps. In this study, citation analysis (institution, country, author, publication, and journal), co-citation analysis (author), co-authorship analysis (institution), and keyword analysis were conducted using VOSviewer software.

Findings

In this study, the findings obtained through bibliometric analysis methods regarding AI applications for individuals with ASD are detailed below.

Distribution of Studies by Year

When Figure 2 is examined, a notable increase is observed in the distribution of analyzed studies by year. Particularly since 2018, there has been a steady growth in the number of publications in this field. For instance, while only 57 articles were published in 2018, this number reached 300 by 2024. This increase reflects the growing interest in ASD and AI topics, as well as the rapid advancements in technology.

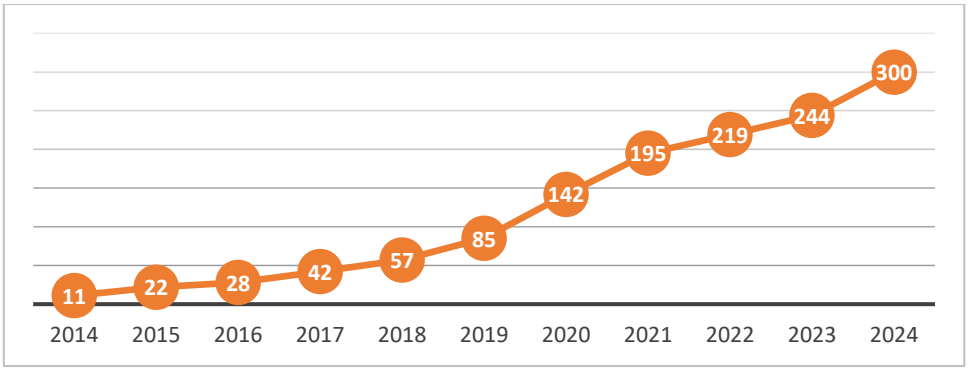

Figure 2. Distribution of Studies by Year

Distribution of Studies by Journals

When Figure 3 is examined, the prominent journals include *Scientific Reports* and *Frontiers in Psychiatry*. These journals are considered important sources of literature in both ASD and AI. In particular, *Scientific Reports* was the journal with the highest number of publications in this field, totaling 47 articles.

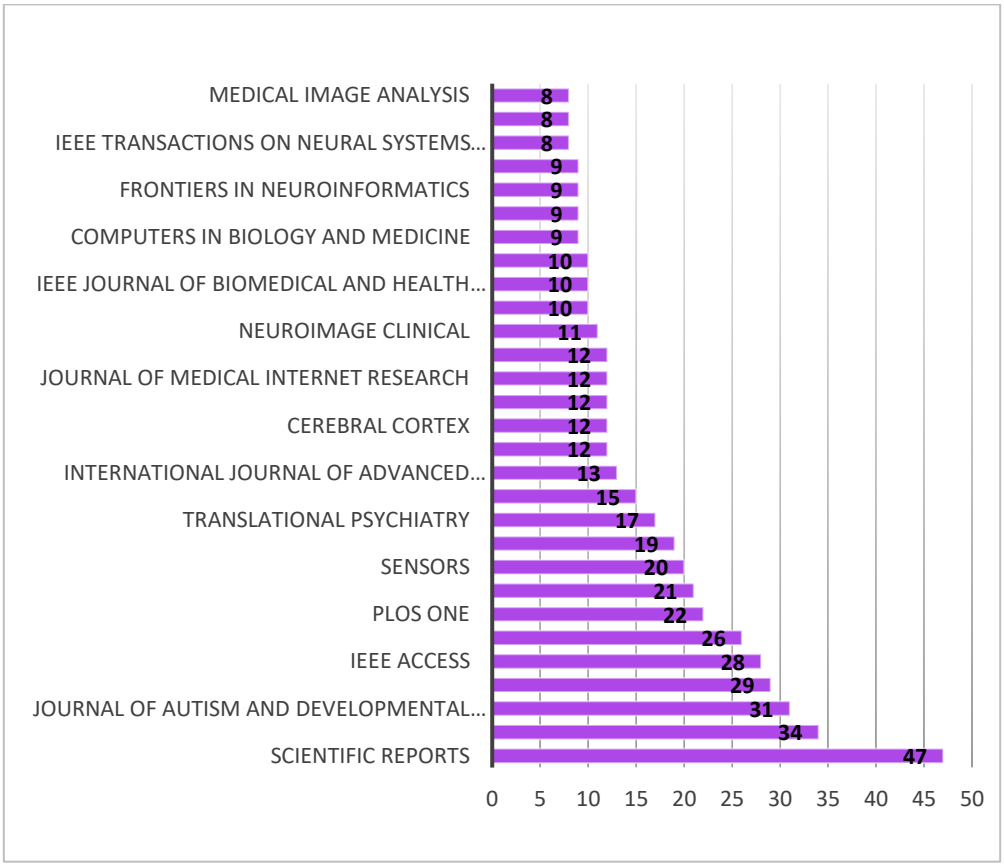

Figure 3. Distribution of Studies by Journals

The Most Frequently Used Keywords

In the frequency analysis of keywords observed in the network visualization map in Figure 4, generated using the

VOSviewer software, the most frequently used terms include *autism spectrum disorder*, *machine learning*, and *autism*. These keywords represent the fundamental research topics and popular methodologies in the field. For instance, the term *autism spectrum disorder* appeared in a total of 521 articles, *machine learning* in 344 articles, *autism* in 215 articles, and *deep learning* in 147 articles. Detailed information regarding the keywords is presented in Table 2.

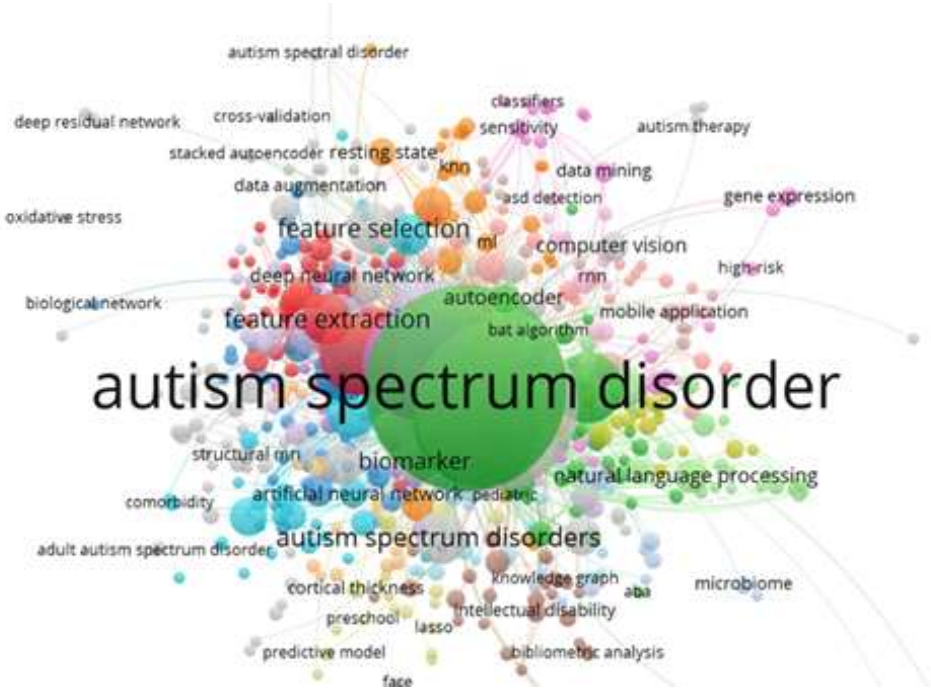

Figure 4. Co-occurrence of All Keywords

Table 2. Distribution of Keywords used in Publications

Keywords	f
autism spectrum disorder	521
machine learning	344
autism	215
deep learning	147
ASD	88
classification	81
autism spectrum disorder (ASD)	80
artificial intelligence	63
FMRI	54
functional connectivity	43
diagnosis	34

The Most Productive Countries/regions, Institutions, and Authors

Distribution of Studies by Country

When Figure 5, which illustrates the geographical distribution of studies, is examined, it is concluded that the

countries conducting the most research in this field are the USA, China, and India. A total of 32% of the publications originate from the USA, followed by China with 23% and India with 12%. The particularly high publication volume of the USA can be attributed to the diversity of its research infrastructure and the availability of funding sources in the country.

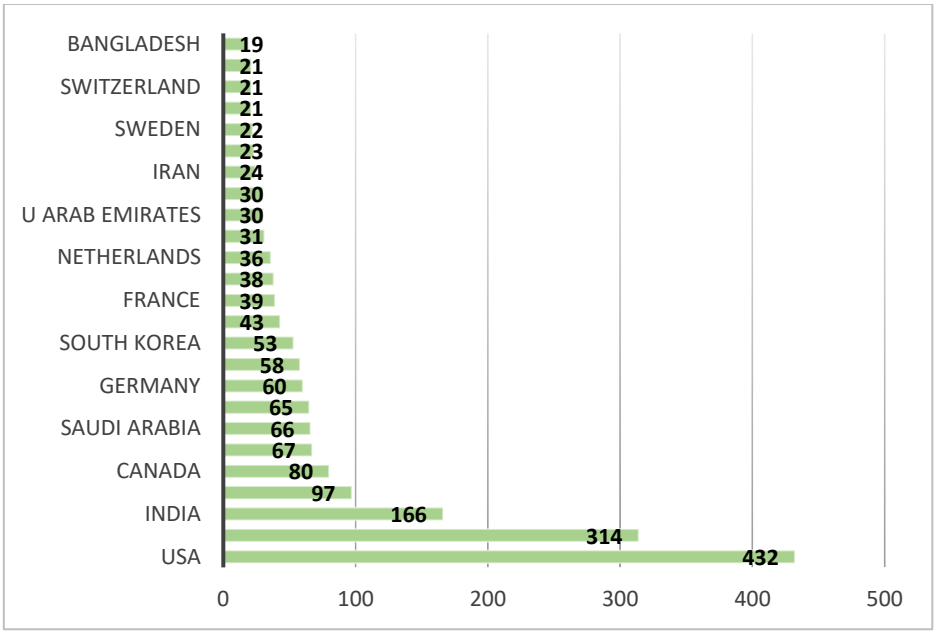

Figure 5. Distribution of Studies by Country

Distribution of Studies by Authors

According to Figure 6, among the analyzed authors, Dennis Wall has the highest number of publications, with a total of 30 articles. However, other prominent authors include Peter Washington and Aaron Kline. This finding highlights the significant contributions of certain researchers to this field.

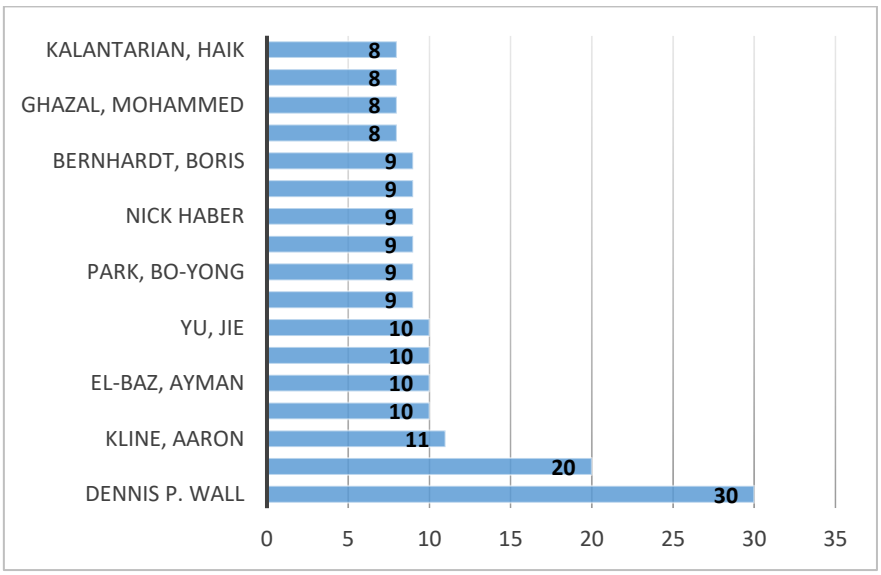

Figure 6. Distribution of Studies by Authors

Co-authorship of Authors

According to the co-author analysis presented in Figure 7, a network map was created by applying the criteria of at least one citation and at least one cited publication to identify the most collaborative and interconnected authors. This analysis revealed distinct collaboration networks in the field of ASD and AI. Robert T. Schultz stands out as the central figure in a large red cluster, while Geraldine Dawson, Xiaoli Li, Kiyoto Kasai, Xia-an Bi, and Kai Wang emerge as key figures in independent clusters. Authors such as Adriana Di Martino and Tony Charma act as bridges between different groups, whereas individuals like Catherine Lord are concentrated in their own clusters with more limited collaborations.

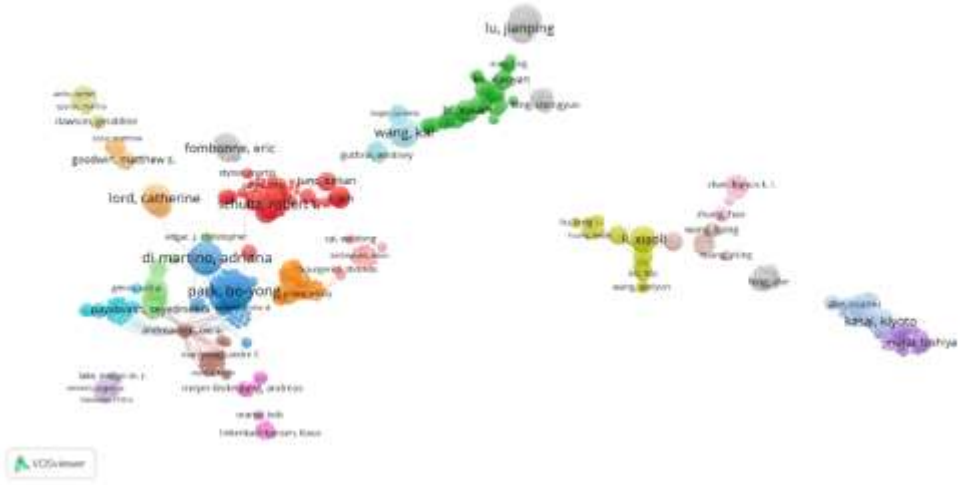

Figure 7. Co-authorship of Authors

Citation of Authors

Figure 8, which visualizes the citation analysis of authors, highlights the leading researchers in the field and their relationships.

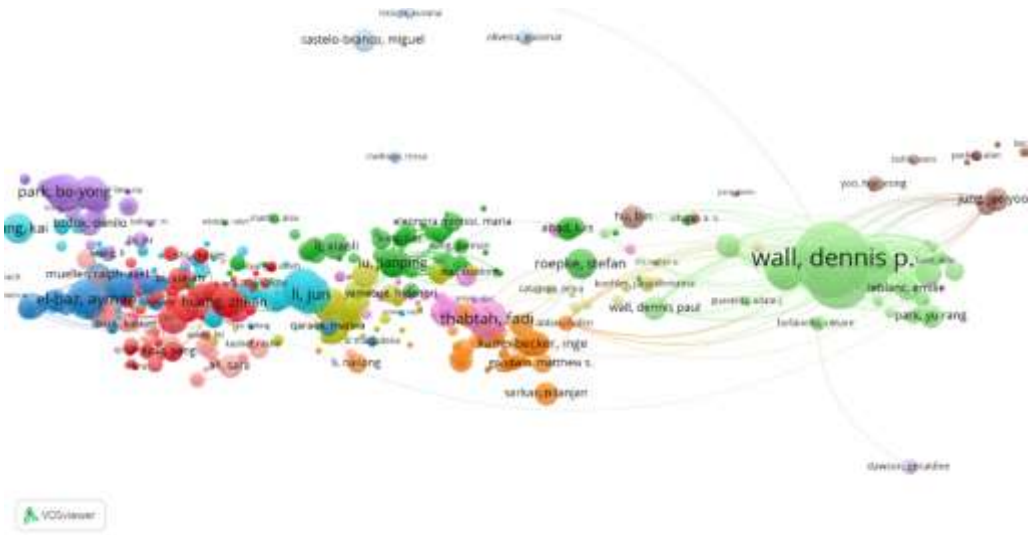

Figure 8. Citation of Authors

Dennis P. Wall and his group of researchers, represented by the orange cluster, exhibit a dense citation and collaboration network. Additionally, Fadi Thabtah, Zhi-an Huang, and Jun Li play a significant role in forming key focal points and strengthening connections between different groups. This structure indicates a concentration of collaboration among specific research groups and suggests that the field is shaped around certain leading researchers.

According to Table 3, Dennis P. Wall, with 17 publications and 540 citations, and Peter Washington, with 15 publications and 455 citations, stand out as the most influential and productive researchers. Fadi Thabtah and Aaron Kline are also among the highly cited researchers, each with 10 publications. Overall, certain researchers in the field of ASD and AI distinguish themselves through both their citation impact and research productivity.

Table 3. Distribution of Studies by Authors, Number of Citations and Link Strength

Author	Number of Publications	Number of Citations	Link Strength
Dennis P. Wall	22	952	1008
Peter Washington	18	577	837
Aaron Kline	11	321	555
Fadi Thabtah	10	362	297
Ayman El-Baz	10	182	282
Lingyu Xu	10	130	114
Jie Yu	10	130	114
Jun Li	10	138	120
Bo-Yong Park	9	76	137
Haik Kalantarian	8	303	316
Kaitlyn Dunlap	8	176	261
Enzo Grossi	8	199	149
Adriana Di Martino	8	173	148

Citation of Countries

When Figure 9 is examined, the United States , represented by the largest node, exhibits an extensive collaboration and citation network with other countries, indicating that it is the most influential country in the field. Countries such as Canada, India, England, and Japan also stand out due to their strong collaborations, while countries such as Italy, Australia, and the United Arab Emirates are represented by smaller yet dense regional connections.

When Table 4 is examined, the USA, with 431 publications and 14,167 citations, is the country that receives the most citations and produces the highest number of publications on ASD and AI, making it the leading country in terms of research influence and connectivity. The USA, China, India, England, and Canada stand out among the countries with the highest number of publications and citations in this field. In particular, the USA, China, and India exhibit strong connectivity, highlighting the presence of international collaborations among researchers in this area.

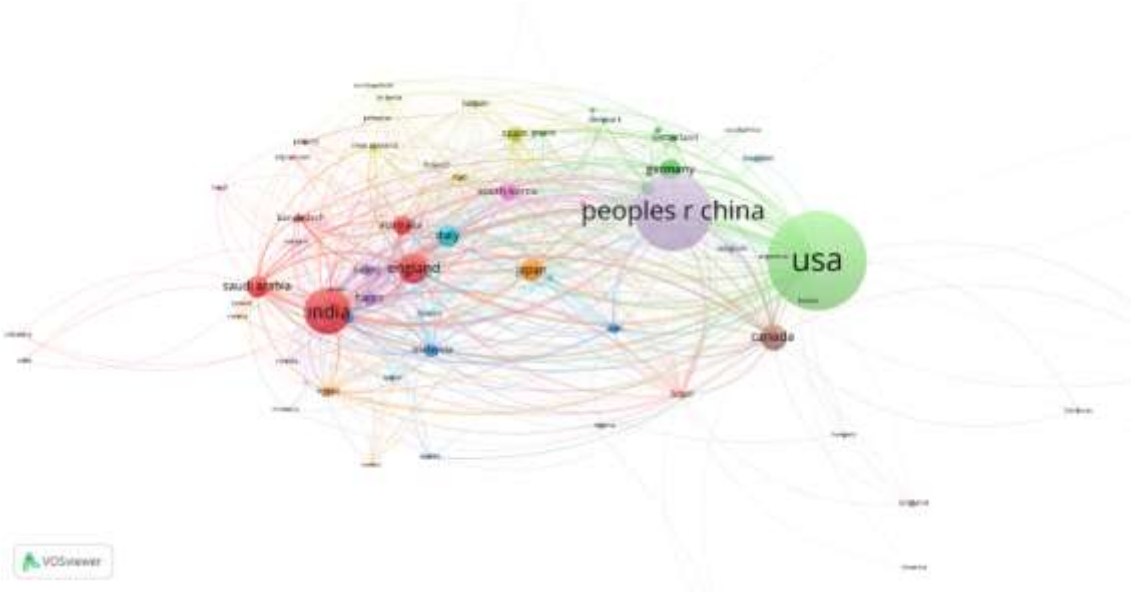

Figure 9. Citation of Countries

Table 4. Distribution of Studies by Country, Number of Citations and Link Strength

Country	Number of Publications	Number of Citations	Link Strength
USA	431	14167	1591
China	313	4559	1205
India	165	1102	754
England	96	2454	479
Canada	79	3393	380
Japan	66	1238	194
Saudi Arabia	65	914	377
Italy	64	1194	216
Germany	59	1499	144
Australia	57	913	251
South Korea	52	601	243
Spain	42	726	86
France	38	669	68
Malaysia	37	407	177
Netherlands	35	666	90

Citation of Organizations

According to Figure 10, a visualization map of institutional citation analysis, Stanford University demonstrates its global academic influence by establishing extensive connections with other institutions. Asia-based institutions, such as the Chinese Academy of Sciences and Shenzhen University, are notable for their strong regional and international collaborations.

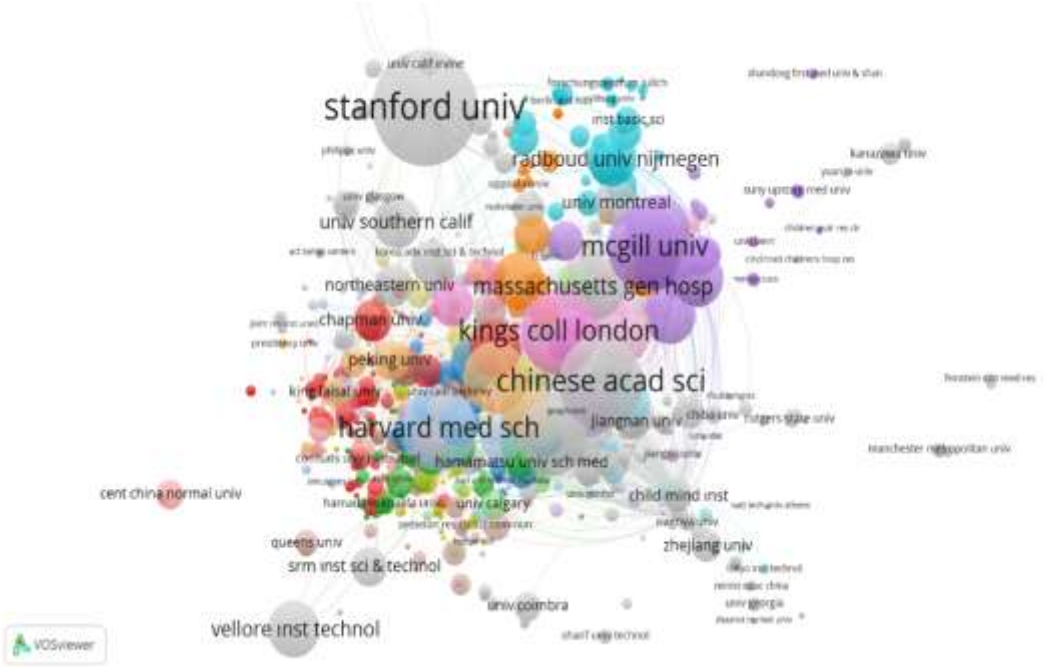

Figure 10. Citation of Organizations

Table 5. Distribution of Studies by Institutions, Number of Citations and Link Strength

Institutions	Number of Publications	Number of Citations	Link Strength
Stanford University	39	1935	323
Chinese Academy of Sciences	29	1073	305
King's College London	27	611	162
McGill University	26	1332	393
Harvard Medical School	26	805	285
Shenzhen University (SZU)	23	418	391
University of Pennsylvania	21	2467	391
Beijing Normal University	21	342	374
MIT	18	1340	192
Massachusetts Gen Hosp	18	970	124
University of North Carolina	16	1118	356
University of Alberta	16	1134	292
University of Cambridge	16	437	181
Vellore Institute of Technology	16	138	97
Harvard University	16	1183	95

According to Table 5, Stanford University and the University of Pennsylvania stand out as the institutions with the highest number of publications and citations. Additionally, the University of Pennsylvania, McGill University, and Shenzhen University distinguish themselves through their extensive academic collaborations. Overall, institutions based in the United States and China play a dominant role in ASD and AI research.

Discussion and Conclusion

In this study, a bibliometric analysis was conducted on the use of AI technology for individuals with ASD. The findings obtained from the analysis indicate that AI technologies are utilized in both ASD diagnosis and teaching processes and that research trends in this field have been steadily increasing. When the research findings are examined, it is observed that the rise in publications in this field since 2018 coincides with the rapid advancements in AI technology.

When the distribution of publications analyzed in this study is examined by country, the USA is identified as the leading country in terms of the number of publications. In this context, the fact that 32% of the total analyzed publications originate from the USA can be attributed to the country's robust infrastructure and financial resources in the field of AI (Akhmadieva et al., 2023). Similarly, countries such as China and India are among the most active contributors in this area. The significant increase in publications from China, in particular, has been linked to the country's financial investments in AI-supported tools and government policies, as highlighted in a study conducted by Knox (2020). This study found that research originating from the USA, China, and India has a strong impact. Therefore, it is recommended that researchers from other countries prioritize institutional and international collaborations to enhance the quality and impact of their research.

When the author and keyword analyses are examined, certain researchers and concepts in the relevant field stand out. The prominence of researchers such as Dennis Wall, Peter Washington, and Aaron Kline in this field indicates that they play a crucial role in the application and development of AI technology for individuals with ASD. In their study, Li et al. (2020) aimed to enhance the emotion recognition skills of individuals with ASD using deep learning algorithms and concluded that these skills improved significantly in the targeted individuals. The fact that the most commonly used keywords in publications on AI applications for individuals with ASD include "autism spectrum disorder," "machine learning," and "deep learning" reflects the general research trends in the field.

When the literature is reviewed, it is observed that AI technology not only accelerates the diagnostic processes of individuals with ASD but also enhances their learning experiences. In particular, numerous studies have demonstrated that AI supports the social interactions, emotion recognition skills, imitation abilities, and communication skills of children with ASD (Kumazaki et al., 2018; Peca et al., 2014; Zhang et al., 2022). Additionally, AI technologies play a critical role in the early and accurate diagnosis of individuals with ASD, significantly expediting the diagnostic process (Kim et al., 2022; Erden et al., 2021; Zhao et al., 2021).

In conclusion, this article presents a comprehensive bibliometric analysis from a global perspective on the development of AI use in education for individuals with ASD over the past 10 years. The findings from this research provide insights into how AI technology can be utilized to meet the needs of individuals with ASD. These insights help academics gain a deeper understanding of the development and current status of research on AI applications for individuals with ASD. Publications on AI use for individuals with ASD have steadily increased over the past five years, indicating the growing popularity of this topic. Therefore, it is recommended that

researchers continue to focus on this area in the future, as both applied and academic studies are needed to enhance the implementation of AI technology for these individuals. In particular, further research is encouraged to improve personalized teaching processes and early diagnosis methods.

Limitations

The data obtained within the scope of this study is limited to the WoS database, therefore, studies in other databases could not be examined within the scope of this analysis. In addition, the study examined the use of AI technology only in individuals diagnosed with ASD. Another limitation is that the study only covers studies conducted between 2014-2024.

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