Unveiling Insights: A Comprehensive Bibliometric Analysis of Generative Artificial Intelligence

G. Lithesh[1], N. V. Y. Naga Sai[1], T. Sai Teja[1], K. Purna Prakash[2,*], Y. V. Pavan Kumar[3,*], K. Ravindranath[1], and G. Pradeep Reddy[4]

[1]Department of Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram 522502, Andhra Pradesh, INDIA

[2]Department of Computer Science and Engineering, Siddhartha Academy of Higher Education, Kanuru 520007, Andhra Pradesh, India

[3]School of Electronics Engineering, VIT-AP University, Amaravati 522237, Andhra Pradesh, INDIA

[4]Department of Information and Communication Technology, Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal 576104, Karnataka, INDIA

*Corresponding Emails : kpurnaprakash@vrsiddhartha.ac.in; pavankumar.yv@vitap.ac.in

Received July 11, 2024, Revised October 21, 2024, Accepted December 15, 2024, Published June 30, 2025

Abstract. *Generative artificial intelligence (GAI) has become prominent in recent days. It has changed the facets of artificial intelligence and is widely implemented in various fields. GAI and its applications have a great influence on society. Hence, to understand its importance and influence well, a comprehensive bibliometric analysis of GAI is proposed in this paper. This bibliometric analysis aims to explore the bibliometric data in terms of challenges, proposed methods, applications, and insights. Further, it is a quantitative tool for evaluating scholarly publications. The proposed bibliometric analysis is performed on the bibliometric data collected from the Scopus (753 records) and Web of Science (400 records) databases ranging from 2013 to 2024 and 448 unique records are considered for the analysis. Further, after scrutiny of these records, 46 records are considered to discuss various applications of GAI. The proposed review is executed systematically by using the PRISMA model. To conduct the analysis, ten critical research questions are identified, and the answers are obtained through the results of the proposed analysis. The key results of this bibliometric analysis unveil various insights into GAI research in terms of impactful applications (22), patterns, research trends, the progress of GAI over the years, scholarly articles production, trending topics, acknowledged collaborative dynamics of authors, affiliations, and countries (10), top influencing authors (10), affiliations (10), and sources (10). These insights drive future aspiring researchers to understand the significance of GAI in various applications and enable them to carry out fruitful research.*

Keywords:

Artificial intelligence, Bibliometric analysis, Generative artificial intelligence, Merging bibliometric data, PRISMA, Scopus, Web of Science.

1. Introduction

Generative artificial intelligence (GAI) refers to a class of AI algorithms and models that is designed to generate new content such as text, images, video, audio, etc., that is similar to the data on which it was trained. These models are capable of creating new data instances by learning the underlying patterns and structures of the data input during the training process. GAI is at the forefront of innovative breakthroughs in the vast field of artificial intelligence, carving out a specialized niche for autonomously creating different content such as text, graphics, and music [1]. Given the rising importance of GAI across various applications, this paper focuses on a detailed bibliometric analysis, attempting to grasp the complexities of the huge literature on GAI. Using bibliometrics as a guiding technique, the patterns of publications, citations, and collaboration networks that define this dynamic and inventive field are explored. To begin this exploration, the fundamentals of GAI should be understood. This technology represents a paradigm change, allowing machines to develop material independently while replicating human ingenuity. This covers a wide range of uses, from creating intelligible text sections to creating intricate visual designs. The ability of GAI to transcend traditional boundaries in content creation has sparked enormous interest and represents a revolutionary force across multiple industries. As we begin bibliometric study, our lens focuses on key factors that provide a comprehensive view of the landscape. One such aspect is the historical progression of research paper output in the field of GAI [2]. By tracking the trajectory of scholarly outputs across time, we hope to identify patterns that reflect the field's evolving phases and milestones.

Understanding how the volume of research has increased or decreased can reveal trends and emphasis points that have influenced the development of GAI. In parallel, the analysis of highly cited articles, hoping to find works that have had a significant impact on the debate

around GAI is done. These major papers act as beacons, pointing academics and practitioners to fundamental information while also changing the field's contours. Recognizing these foundational works provides insights into the intellectual genealogy that supports today's GAI research. Collaboration is a key component of scientific development, and the network of collaborations among researchers in GAI is another focus of our investigation. Unraveling the extensive web of links between scholars reveals the collaborative dynamics that shape knowledge development in this domain. Identifying critical nodes in this network and comprehending the flow into the research of GAI as we progress through this bibliometric inquiry, it is critical to note that the impact of GAI goes beyond academic curiosity. This technology has spread throughout numerous industries, changing the landscape of creativity, innovation, and problem resolution. GAI is having a profound impact on industries ranging from journalism and advertising to entertainment and healthcare.

To summarize, this bibliometric analysis aims to provide more than just a snapshot of the current GAI research field. It seeks to establish a solid foundation for understanding the subtle development and overarching significance of GAI within the larger context of artificial intelligence. By finding impactful applications, patterns, and trends, and acknowledging collaborative dynamics, this analysis hopes to add meaning to the continuing discussion, encouraging a better knowledge of the dynamic and imaginative realm of GAI [3]. By defining appropriate research questions (RQs) as follows, the intended outcomes are obtained based on the paper's above-mentioned purpose and the body of literature that is already available. These research questions make it easier to find significant publications, authors, studies, affiliations, and countries within the topic over time.

RQ1. What are the key applications of GAI in various disciplines?

RQ2. What is the annual production of articles from 2018 to 2024?

RQ3. Who are the contributory authors of the most relevant articles on this topic?

RQ4. Which are the most relevant sources on this topic?

RQ5. Which are the most relevant and impactful affiliations?

RQ6. Which countries are most cited GAI?

RQ7. What are the most cited documents globally on GAI?

RQ8. What are the most important keywords related to GAI?

RQ9. Who are the collaborating authors on the most relevant studies of GAI?

RQ10. What is the countries' collaboration on the most relevant studies of GAI?

The journey through the annals of GAI research provides a road map for future discovery and innovation, pointing researchers in new directions in this cutting-edge subject. GAI has various uses, including text/image generation, data augmentation, style transfer, and performing creative tasks like producing art or music. However, it also raises ethical concerns, such as producing deepfakes or fake content. State-of-the-art literature works that are executed in these impactful applications are summarized in Table 1. The significant literature works mentioned in Table 1 showcase the importance and influence of GAI in various fields namely neuro imaging, content writing, medical education, deepfake, image generation, physiology, gaming, ethical concern, human resource management, chatbot, prompt engineering, healthcare, economics, education, GAN, security, generative recurrent network, medical chemistry, recurrent neural network, AI, and unsupervised learning.

Table 1 Literature works on applications of GAI

Application	Year	Description			Ref.
		Concept	Challenges	Future Scope	
Neuro Imaging	2023	▪ The combination of GAI and brain imaging methods opens new paths for studying brain anatomy and function non-invasively.	▪ The concept of Neuro Imaging is complex to understand and difficult to interpret the behavior of the brain imaging to the GAI.	▪ Research into sophisticated GAI models for brain imaging has the potential to improve brain networks, solve problems, and develop applications in neuroscience and clinical diagnostics.	[4]
Content writing	2023	▪ Deepfake detection emphasizes the importance of combatting disinformation and protecting vulnerable persons.	▪ The fundamental challenge in content writing using GAI is the content that was written by AI can produced by the partial awareness of AI.	▪ Further research and development in using AI for letter writing should focus on refining algorithms to reduce biases and ensure ethical issues.	[5]
Medical Education	2023	▪ The integration of GAI models such as ChatGPT in healthcare has the potential to improve education, research, and clinical practice, demanding the creation of standardized rules for their safe use.	▪ The study of medicinal science and performing it physically requires good knowledge and understanding of the core point in minute detail.	▪ Improve education, research, and clinical practice, demanding the creation of standardized rules for their safe use.	[6]
Deepfake	2023	▪ The use of GAI for the creation of letters of reference has the potential to reduce hidden biases and enhance	▪ The usage of Deepfake should be ethical and aware otherwise it would become the problem of	▪ Deepfake detection should focus on improving fusion techniques, investigating innovative machine	[7]

		fairness in higher education and professional success.	privacy.	learning methods, and building strong benchmarks.	
Image Generation	2023	▪ The incorporation of Midjourney, the next GAI tool, within design education, promotes creative thinking and broadens the imagination of future designers through organized prompts and picture development.	▪ There is a high chance of generating an image with low quality without giving proper guidance about the resultant image.	▪ GAI within design education promotes creative thinking. ▪ Highlights the imagination of future designers by organized prompts and picture development.	[8]
Physiology	2023	▪ Motor neuron terminals have high energy needs, spurring research into phosphagen kinase mitochondrial decorating and bioenergetic deficiencies caused by arginine kinase 1 (ArgK1) knockdown.	▪ Understanding the principles of energy control in motor neurons, as well as resolving bioenergetics caused by ArgK1 knockdown, are difficult issues for neuromuscular research.	▪ Further exploration is needed to elucidate the role of phosphagen kinases in motor neuron bioenergetics, potentially leading to therapeutic strategies for neuromuscular disorders characterized by bioenergetic dysfunction.	[9]
	2023	▪ Physiology is a field of medical sciences that consists of very complex theories and understanding of the physiological processes governing human health/diseases.	▪ The presence of phosphagen kinases in motor neuron terminals indicates an energy storage and buffering mechanism similar to fast-twitch muscle fibers, which affects bioenergetics and function.	▪ Further research into the involvement of phosphagen kinases in motor neuron bioenergetics. ▪ This provides insights into neuromuscular illnesses and guides possible treatment methods targeting mitochondrial function and energy metabolism.	[10]
Gaming	2023	▪ In this study, they used the analytical technique of evolutionary game analysis (EGA) to investigate the potential of AI in the future of education.	▪ The public has access to GAI, particularly in the field of education. While proper AI applications have the potential to greatly improve education, misuse of technology might have negative effects.	▪ According to this study, the school may offer useful advice on game analysis and achievable recommendations to support students' academic success and the adoption of emerging trends in AI education.	[11]
	2023	▪ Balancing the interests of copyright holders, promoting AI innovation, and maintaining legal compliance presents hurdles when navigating the legal environment of AI-generated material.	▪ Copyright difficulties with GAI systems, such as ChatGPT, demand legal changes to handle authorship and ownership complications in AI-generated material.	▪ To secure intellectual property rights in the digital era and promote innovation, future research should concentrate on creating legal frameworks. ▪ It strikes a compromise between advancing AI developments and maintaining copyright interests.	[12]
Ethical Concern	2023	▪ In the age of new technology and advancements in artificial intelligence, it is becoming a challenge to maintain ethical concerns in society.	▪ Educating middle school kids about GAI approaches promotes digital and AI literacy, allowing them to engage critically with the societal and ethical consequences of technology.	▪ Integrating GAI literacy can provide students with the necessary abilities to navigate and act responsibly in an increasingly AI-driven society, resulting in a generation of educated and ethical digital citizens.	[13]
	2023	▪ GAI in scholarly publishing presents both challenges and potential, demanding careful consideration and guidance to ensure appropriate use.	▪ Balancing AI's ability to supplement or replace existing procedures with scholarly rigor and ethical standards.	▪ Continued investigation and improvement of recommendations for maximizing AI's benefits while limiting dangers in scientific publishing methods.	[14]
	2023	▪ AI in cosmetic surgery improves patient education, but it faces obstacles such as representation biases and ethical considerations when providing thorough training.	▪ Ensure varied representation, ethical integration, and compliance with medical standards in AI-generated images for cosmetic surgery education.	▪ Further study should concentrate on reducing biases, increasing representation, and developing ethical guidelines for incorporating AI into cosmetic surgery training and teaching.	[15]
	2021	▪ Educating middle school students about GAI promotes digital literacy and ethical awareness, while also addressing Deepfake concerns and encouraging responsible technology use.	▪ Navigating the intricacies of AI-mediated media, encouraging critical thinking, and creating effective teaching solutions to address ethical concerns.	▪ Further study should look into improved educational techniques, legal frameworks, and technological solutions to reduce Deepfake hazards and promote responsible technology use among young people.	[16]
Human resource management	2023	▪ This work discusses and synthesizes the literature on AI and GAI, linking it to many aspects of HRM processes, practices, relationships, and outcomes, helping to shape the future of HRM research.	▪ The work tackles challenges in information technology such as security issues, rapid technological breakthroughs, and data privacy.	▪ GAI is linked to numerous aspects of HRM processes, practices, interactions, and outcomes, helping to shape the future of HRM research.	[17]
Chatbot	2023	▪ Assessing the creativity of GAI in comparison to humans, questioning views, highlighting AI's potential, and investigating future consequences for creativity.	▪ Understanding the distinctions between AI and human creativity, overcoming biases, and developing AI skills for creative jobs.	▪ Further research into GAI's involvement in creativity, including ethical issues and improving AI-human collaboration in creative activities.	[18]
	2023	▪ ChatGPT demonstrates potential as a scientific writing tool, but it raises	▪ Ensuring the accuracy, ethical application, and credibility of AI-	▪ Further research is needed on AI's involvement in scientific writing,	[19]

		concerns about accuracy and ethical problems in medical research.	generated content in scientific and medical writing.	including accuracy, ethics, and integration into research procedures.	
	2023	▪ Investigating ChatGPT's impact on higher education: academic integrity issues, novel assessment design, and potential for underserved students.	▪ Addressing academic integrity, recognizing AI limitations, and ensuring inclusion and student representation in conversations.	▪ More research is needed on AI's function in education, including ethical implications, equal access, and student participation.	[20]
	2023	▪ Integrating OpenAI tools such as ChatGPT and DALL-E into the game development curriculum improves student learning and creativity.	▪ Addressing ethical concerns, assuring technical proficiency, and adjusting to changing AI capabilities and educational requirements.	▪ Further research into AI integration in various educational contexts, facilitating interdisciplinary cooperation, and supporting ethical AI use in student projects.	[21]
	2023	▪ Assessing Japanese stylometric traits indicates differences between ChatGPT and human-generated text, which aids in AI identification.	▪ Addressing the rising sophistication of AI models, assuring the robustness of stylometric analysis, and considering cross-linguistic variances.	▪ Improving AI detection methods, investigating linguistic nuances in AI-generated content, and promoting AI literacy in language studies.	[22]
Prompt engineering	2023	▪ AI rapid engineering is critical for optimizing the performance of huge language models across several domains, emphasizing its importance as a digital skill.	▪ The prompt in the form of text given to any Artificial intelligence should be validated is a big challenge.	▪ AI PROMPT framework, investigating innovative prompting tactics and determining the long-term influence of prompt engineering on the progress of AI technologies and their applications in a variety of disciplines.	[23]
	2023	▪ GAI models, such as ChatGPT, show promise for modernizing Statistical Process Control (SPC) by supplying code, explaining concepts, and producing knowledge, but they confront issues with nuanced tasks and accuracy validation.	▪ Ensuring correct findings and overcoming limits in handling complicated tasks, as well as the necessity for validation and integration with other approaches, all pose hurdles to the use of GAI models for SPC.	▪ GAI models for SPC, developing validation procedures, and integrating complementary methodologies to boost accuracy and reliability in actual applications, increasing efficiency and productivity in SPC practice, learning,	[24]
	2023	▪ In project planning, GAI and human project managers collaborate, highlighting the value of human expertise, and timely engineering in refining AI.	▪ Addressing the distinct strengths and weaknesses of AI-generated and human-generated project plans. ▪ Assuring efficient integration of human and AI skills poses challenges for optimizing project planning processes.	▪ Future research could focus on establishing hybrid approaches that combine the strengths of AI and human project managers, thereby improving the efficiency and efficacy of project planning across multiple industries.	[25]
Healthcare	2024	▪ Evaluating AI-generated images of ulcers for medical education reveals opportunities and problems for improving traditional teaching approaches.	▪ Balancing authenticity and instructional value, improving AI models to provide accurate medical images, and incorporating AI into medical curriculum.	▪ Increasing AI capabilities for medical image production, integrating AI-enhanced resources into medical education, and addressing ethical and regulatory concerns.	[26]
	2023	▪ Exploring LLM uses in ophthalmology reveals prospects, problems, and the need for norms to protect patients.	▪ Ensure accuracy and interpretability, address bias, secure data, and integrate LLMs into ophthalmic practice effectively and ethically.	▪ Creating best practices, standardizing norms, expanding LLM capabilities, and encouraging collaboration to maximize advantages in ophthalmology.	[27]
	2023	▪ Integrating LLMs with hemodialysis data improves personalized care by increasing patient engagement and treatment results.	▪ Continuous data updates, bias reduction, transparency, and the development of reliable AI algorithms for tailored nephrology care.	▪ Working with AI academia, companies, and nephrologists to create transparent, understandable AI models that improve tailored dialysis for patients.	[28]
	2023	▪ Multimodal GAI improves emergency department care by providing accurate and high-quality chest radiograph interpretations, which aids in rapid diagnosis.	▪ Ensure AI accuracy, incorporate AI into clinical workflows, eliminate any biases, and protect patient privacy and data security.	▪ Further validation, clinical practice integration, AI-assisted diagnostic tool creation, and long-term effect and scalability study.	[29]
	2023	▪ Applying military ethical principles to GAI in healthcare, we propose the "GREAT PLEA" framework to solve ethical concerns.	▪ Transparency, bias reduction, ethical implementation, privacy protection, and fair healthcare access.	▪ Adoption, growth, and practical use of the "GREAT PLEA" concept to promote ethical AI integration in healthcare.	[30]
	2023	▪ ChatGPT's evaluation in otolaryngology reveals good agreement with physicians for diagnosis and care in curated scenarios.	▪ Handling unstructured clinical data, maintaining consistent quality, and overcoming limits in difficult circumstances.	▪ Investigation into ChatGPT's effectiveness in a variety of clinical contexts, integration with decision support systems, and diagnostic accuracy enhancement.	[31]
	2023	▪ Using mixed methodologies and online forums to better understand health communication experiences, particularly among excluded groups, increases study inclusion.	▪ Achieving diverse representation, language accessibility, forum interaction, and successful synthesis of qualitative and quantitative data.	▪ Scaling up online forum approaches, overcoming language hurdles, improving engagement strategies, and incorporating results into successful health communication treatments.	[32]
Economics	2023	▪ Using GAI technology, we can provide a new research paradigm for economic	▪ Addressing ethical problems, assuring model openness and	▪ Further investigation of GAI's potential for portfolio management,	[33]

		and financial study.	accountability, eliminating data biases, and adjusting to fast-paced technological advances.	prediction, scenario analysis, policy analysis, and fraud detection in economic and financial studies.	
Education	2024	▪ Evaluating the performance of a conversational AI platform in a medical examination and comparing it to that of residents.	▪ Ensuring accuracy, eliminating restrictions in specific exam portions, and strengthening the AI's skills for medical assessments.	▪ Improving AI's comprehension of medical concepts, question analysis, and feedback to improve test quality.	[34]
	2024	▪ Evaluating ChatGPT's performance in healthcare education assessments, with implications for dentistry education.	▪ Addressing limits in processing image-based queries, improving responses for critical literature appraisal, and managing word count constraints.	▪ Using AI's potential for virtual learning, adjusting teaching techniques, and preventing misuse to improve educational outcomes.	[35]
	2024	▪ Assessing ChatGPT and GPT-4 performance compared to students on NAEP science assessments, emphasizing the need for instructional adaptation.	▪ Balancing cognitive demands, redefining educational objectives, and developing innovative evaluation methods for GAI integration.	▪ In education, emphasis is placed on advanced cognitive skills, critical thinking, and the adaptation of evaluation methodologies for GAI.	[36]
	2023	▪ Addressing the threat of text-generating technologies to educational integrity, we propose watermarking and collaboration with AI as solutions.	▪ Detection reliability, ethical problems, teaching approach adaptation, and watermarking technology limits.	▪ Developing effective detection methods, encouraging collaboration between education and AI, and investigating novel solutions to academic integrity.	[37]
	2023	▪ Understanding ChatGPT's impact on higher education through ethnographic research, resolving integrity concerns, and directing appropriate integration.	▪ Academic integrity, plagiarism detection, critical thinking decline, policy formation, user views, and empirical research gaps.	▪ Developing guidelines, investigating user experiences, improving ethical integration, and expanding AI research in education.	[38]
	2023	▪ Investigating the influence of GAI in higher education, with an emphasis on academic integrity, biases, and equity, as well as encouraging AI literacy and ethics.	▪ Academic integrity, bias detection, justice, equity, cultural competency, false allegations, language assistance.	▪ Enhancing AI literacy, promoting justice, removing biases, providing equal access, and assisting educators in effectively utilizing AI tools.	[39]
	2023	▪ Creating institutional policies for AI in higher education that promote ethical use and inclusion, and improve educational processes and research.	▪ Defining AI scope, ethical considerations, inclusion, knowledge base, transparency, digital transformation, and the distribution of best practices.	▪ Additional study on knowledge base, transparency, ethics, and creating educational environments that promote digital transformation and beneficial practices.	[40]
	2023	▪ Comparing the effects of GAI platforms vs traditional ones on narrative intelligence and writing self-efficacy among undergraduate students.	▪ Ensure platform usability, address ethical problems, assess long-term impact, and encourage creativity and critical thinking.	▪ More research on diverse student populations, including identifying potential biases and improving platform features for tailored learning experiences.	[41]
Generative Adversarial Network (GAN)	2020	▪ GAN for the stochastic reconstruction of digital core pictures improves representation accuracy and morphological similarity, which is especially useful for digital core physics investigation in shale formations.	▪ The GAN is used in the reconstruction of digital core images which is pre-processed by the three-value-segmentation method that may generate noise in the network.	▪ Further study should focus on improving GAN structures and researching other preprocessing approaches thereby increasing digital core analysis.	[42]
Security	2020	▪ The GAINESIS program improves hardware security by solving problems in identifying hardware trojans (HTs) during the gate-level netlist (GLN) phase.	▪ A significant problem in the field of hardware security consists of hardware trojan (HT) viruses that can lead to security breaches.	▪ Further study might investigate using GAINESIS in other phases of hardware design, as well as developing effective machine learning models for comprehensive HT detection and avoidance.	[43]
Generative recurrent network	2018	▪ GAI models present a fresh approach to chemo genomics and de novo drug design, as they provide researchers with the ability to narrow down their search of the chemical space and focus on regions of interest.	▪ Virtual compound design is made possible by this method without the need for secondary or external activity prediction, which increases the risk of bias or inaccuracy.	▪ The outcomes support the application of our generative RNN-LSTM system for high-impact use cases, including fragment-based molecular design, hit-to-lead optimization for several therapeutic targets, and low-data drug discovery.	[44]
Medical Chemistry	2022	▪ In drug discovery, GAI has been used to increase the amount of chemical space that can be searched for possible drug-like molecules.	▪ Demonstrated promise in the treatment of neurological conditions including Parkinson's and Alzheimer's, but some also have dissociative effects that have prompted the manufacture of illegal medications.	▪ The synthesis and experimental confirmation of these compounds are still necessary. ▪ They give twelve potential antagonists that are not included in current chemical databases to show what kind of process can do.	[45]
	2021	▪ GAI enables de novo chemical design by using deep learning to predict and create novel drug-like molecules with desired properties.	▪ Assuring model generalization to varied chemical domains and addressing potential safety and regulatory concerns all present difficulties to the widespread implementation of GAI in	▪ GAI models, increasing training datasets, and incorporating expert knowledge can improve predictive accuracy and speed up drug discovery procedures. ▪ It paves the way for novel applications	[46]

			medicinal chemistry.	in personalized medicine and therapeutic development.	
Recurrent Neural Network	2022	▪ Integrating the Maximum-caliber route sampling technique into recurrent neural networks allows for the introduction of thermodynamic or kinetic constraints, which improves the modeling of dynamical systems with prior information across several domains.	▪ The Recurrent Neural Network makes it harder to impose prior knowledge or intuition through generic constraints.	▪ Further study can investigate the applicability of this method in a broader variety of GAI models and expand its value to diverse time series datasets in physical, social sciences, and beyond.	[47]
AI	2022	▪ Artificial intelligence models and generic time series in several physical and social scientific fields when one wants to add theory- or intuition-based modifications to limited data.	▪ This recurrent structure enables them to simulate infinitely long memories in the training time series. ▪ It also makes it more difficult to enforce general restrictions that might otherwise impose previous knowledge or intuition.	▪ A route sampling method that incorporates general thermodynamic or kinetic constraints into recurrent neural networks, based on the maximum caliber principle.	[48]
Unsupervised Learning	2021	▪ The focus of the work is on using large volumes of amino acid sequence data to train deep contextual language models using unsupervised learning to capture biological features and evolutionary variability.	▪ The challenge of protein language modeling involves describing biological features in a sophisticated way while also scaling data and model capability for unsupervised learning in GAI.	▪ Future developments include representation learning-based GAI for biology, which will improve the prediction of secondary structure, long-range contacts in proteins, and mutational consequences.	[49]
Image Processing	2024	▪ The Dual-3DM^3 - AD model was a multi-modal fusion technique that used both structural and metabolic information from PET and MRI scans to help diagnose Alzheimer's disease early.	▪ The key hurdles include dealing with the complexities of multi-modal data processing, assuring efficient feature extraction, and meeting the computing needs of working with MRI and PET images.	▪ Future research may concentrate on refining the model quicker, broadening the scope of its validation on more extensive and varied datasets, and combining it with additional biomarkers like genetic data to improve early detection.	[50]
	2024	▪ The Multi-scale GC-T2 framework is an automated diagnosis system for melanoma skin cancer detection, which employs sophisticated approaches to improve lesion segmentation and classification.	▪ Key challenges include dealing with the significant visual similarities among various skin lesions and the substantial intraclass variations, which can hinder accurate segmentation and classification.	▪ Future studies could concentrate on increasing the model's robustness by including larger and more diverse datasets to increase generalization and accuracy.	[51]
	2024	▪ This study proposed an integrated strategy for reliable human motion detection in challenging circumstances, focusing on occlusions. ▪ It combines Adapted Canny Edge detection, a modified Mask R-CNN for segmentation, and a Hybrid RDA-WOA-based RNN for classification.	▪ Key issues include successfully recognizing human motion in circumstances with severe occlusions, when people may be partially or completely concealed by other objects.	▪ Future research should look into how the proposed methodology works in different environments, such as congested public venues or dynamic metropolitan settings, to validate its resilience.	[52]
	2023	▪ The Deep Dual-Patch Attention Mechanism (D2 PAM) is a deep learning-based approach designed to improve the prediction of epileptic seizures by classifying brain signals.	▪ Key challenges include handling the high variability in brain activity between patients, collecting large, high-quality datasets for training, and ensuring model generalization across diverse populations.	▪ Future research will focus on validating the model on larger, more diverse patient datasets, and personalizing models for individual patients.	[53]
	2023	▪ This study offers a strategy for using radiological imaging to distinguish between COVID-19 pneumonia, other types of pneumonia, and particular variants like Omicron. To increase the accuracy of the diagnosis, it uses three CNNs.	▪ The primary obstacles include limited datasets, which might impair CNN models' generalization and accuracy, and the difficulty of differentiating pneumonia patterns brought on by different COVID-19 variations.	▪ To increase model accuracy and generality, future research might concentrate on growing the dataset. ▪ It might also incorporate more data, such as clinical symptoms or genetic information, to identify COVID-19 variants more precisely.	[54]

The systematic identification of various GAI applications and the analysis of GAI's bibliometric data in several aspects such as the challenges involved in implementing these applications, the future scope of these applications, progress of GAI over the years, scholarly articles production, trending topics, collaboration of authors, affiliations, and countries, top influencing authors, affiliations, and sources in this research domain is the key contribution of the proposed bibliometric analysis. Further, GAI significantly impacts applications such as ethical concerns, chatbots, healthcare, and education where several challenges need to be addressed by considering the future directions. GAI applications in several important fields and services are depicted in Fig. 1. The applications presented in Fig.1 addressed RQ1.

This paper makes significant contributions to the field of generative artificial intelligence (GAI) through a comprehensive bibliometric analysis of 1,153 records from the Scopus and Web of Science databases. It identifies key trends and research patterns; and provides a detailed overview of the development and evolution of GAI research. The research highlights influential publications, prolific authors, and leading institutions,

helping to recognize foundational works and key contributors shaping the field. Additionally, it maps collaborative networks among authors, institutions, and countries, revealing the global research landscape and identifying research hotspots. By summarizing the current state of GAI research and highlighting existing gaps, this paper offers valuable insights that can guide future research directions and inform further exploration in this rapidly evolving field.

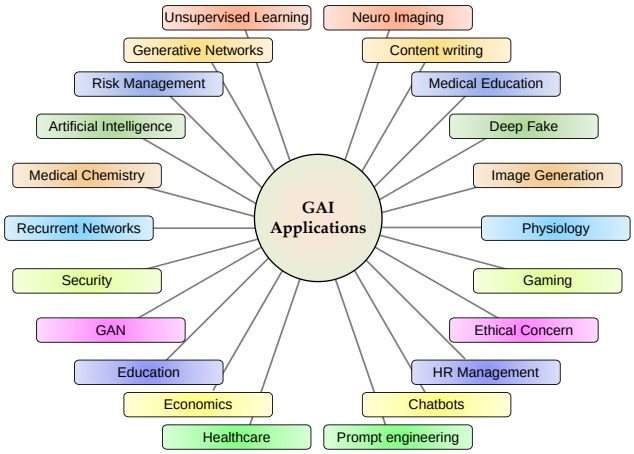


Fig. 1 Key applications of GAI.

The remaining sections of the paper are organized as follows. Section 2 describes the methodology, Section 3 presents the results, and Section 4 presents the conclusions drawn from the study.

2. Methodology

To conduct the proposed analysis, the accurate dataset is taken from the Scopus and the Web of Science (WoS) databases. Based on the PRISMA ("Preferred Reporting Items for Systematic Reviews and Meta-Analyses") model, the dataset has undergone the exclusion of unrelated records. The search queries used for the proposed analysis are given in Table 2 and Table 3.

Table 2 Search query for Scopus bibliometric data

Search query used in Scopus database
TITLE-ABS-KEY ("generative artificial intelligence") AND PUBYEAR > 2012 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (LANGUAGE, "English"))

Table 3 Search query for WoS bibliometric data

Search query used in WoS database
"generative artificial intelligence" (All Fields) and 2018 or 2020 or 2021 or 2022 or 2023 or 2024 (Publication Years) and Article or Review Article (Document Types) and English (Languages)

A. Search query used in Scopus Database

Firstly, based on the keyword “generative artificial intelligence” the filtration of data is done. Next, the year filter is applied by considering the year range from 2013 to 2024 to extract the records. So, PUBYEAR > 2012 and PUBYEAR < 2025 are used. Further, the search is limited to only articles and review articles by using LIMIT-TO (DOCTYPE, “ar”) OR LIMIT-TO(DOCTYPE, “re”), where “ar” stands for articles and “re” stands for review articles. In continuation, the source type is limited to the journal by using LIMIT-TO(SRCTYPE,”j”), and the language is limited to English by using LIMIT-TO(LANGUAGE, “English”). Lastly, the search is limited to the articles in the final publication stage instead of in press by using LIMIT-TO(PUBSTAGE, “final”).

B. Search query used in WoS Database

The search is continued in the WoS based on the same keyword “generative artificial intelligence” and the filtration of data is done by considering all fields. The year filter is applied to the extracted records by considering the available years 2018, 2020, 2021, 2022, 2023, and 2024 in the WoS database. Hence, the years, “2018 or 2020 or 2021 or 2022 or 2023 or 2024 (publication years)” is used in the query. Further, the search is limited to only articles and review articles by using “article or review article (document types)”. Lastly, the language is limited to English by using English (Languages).

C. PRISMA model for bibliometric analysis

The datasets gathered from the Scopus database and Web of Science (WoS) database, will be merged to get a final dataset [55]. This final dataset consists of unique records of bibliometric data that are ready for conducting the proposed analysis. To carry out this, the required libraries such as “readxl” and ”bibliometrix” are installed and the respective libraries are loaded into the R environment. The search and scrutiny process of retrieving records using the PRISMA model is shown in Fig. 2 and a detailed explanation of this process is given as follows. The initial search was done in the Scopus and WoS databases and the bibliometric data was considered up to 14 February 2024. The records were extracted from Scopus for the range of years 2013-2024 and in the WoS for the years 2018 and 2020-2024. Based on several criteria such as topic-related, year of publication, source type, language, document type, and publication stage, records have been reduced.

The initial search extracted 753 records from the Scopus database and 400 records from the WoS database based on the keyword “generative artificial intelligence”. By applying the year filter on these 753 records, based on the year of publication (2013 – 2024), 612 records were extracted from Scopus. Similarly, for the years (2018, and 2020 – 2024), 400 records were extracted from the WoS. Further, 368 records from Scopus and 300 records from WoS were extracted based on the document type i.e.,

article and review criteria. The criterion source type (journal) resulted in 362 records from Scopus and no criterion in WoS for this. The criterion publications stage (final) resulted in 305 records from Scopus and no criterion in WoS for this. Finally, the criterion language (English) was considered in both Scopus and WoS and it resulted in 283 records and 297 records from Scopus and WoS respectively. These records were considered for further scrutiny.

After reading each record's title, 188 records were identified as relevant to this study, and 260 records were excluded. After reading the abstract of every record, 131 records were identified as relevant, and 57 records were excluded. Further, based on inaccessibility to full text, 68 records were identified and excluded, and the considered records were 63. Finally, after the valuation of the full text of each record, 46 records were identified for the literature and 17 records were excluded.

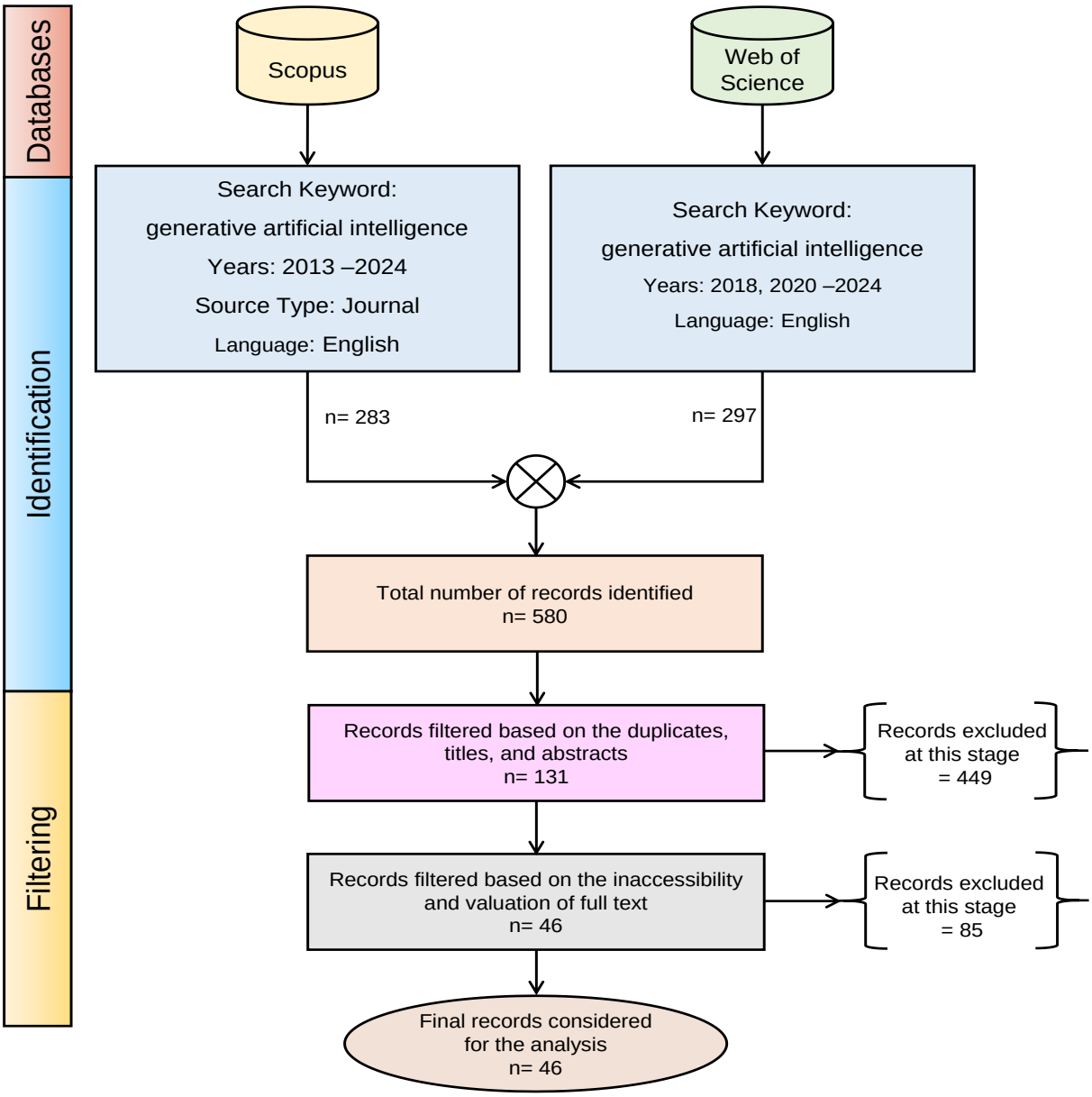


Fig. 2 PRISMA model for retrieving records.

3. Results and Discussions

The results of the key insights, patterns, and trends of the GAI bibliometric data are presented in this section. The annual production of articles in the GAI research domain is shown in Fig. 3. In this, it is observed that the production of articles in 2018 is 2, in 2019 and 2020 is 0, in 2021 and 2022 is 7, and there is a drastic growth in 2023 with 385 articles. Further, it is observed that there is a production of 45 articles in 2024. The total production of articles is 446, and the bibliometric data are considered up to 14 February 2024. The annual production of articles from 2018 to 2024 shown in Fig. 3 addressed RQ2.

The research landscape of GAI is depicted in Fig. 4 indicating author prolificacy and addressed RQ3. Notably,

luminaries such as LEE M, KSHETRI N, and WANG Y stand out at the top, demonstrating their significant contributions to the subject. This figure not only measures their productivity but also represents the cumulative impact of these scientists on the intellectual discourse of GAI. The ascending sequence of authors, aligned with ascending bars, creates a clear hierarchy, allowing for a more intuitive comprehension of research production. Beyond enumeration, this image captures a narrative of intellectual contributions, collaborative networks, and the dynamic search for knowledge in GAI, providing a captivating glimpse of the field's variegated terrain. The generated results that demonstrate the authors' productivity over a certain time are shown in Fig. 5. This figure shows that the author "LEE M has published the highest number of articles (9) in 2023. Further, the observations made from this figure present the paper output increased by the authors between 2023 and 2024 compared to previous periods. This suggests a significant increase in research production throughout this period. The temporal study sheds light on the changing dynamics and growing interest in GAI among the academic community, particularly during the given years. This increase in productivity could be due to innovations, rising trends, or a renewed focus on GAI throughout the period.

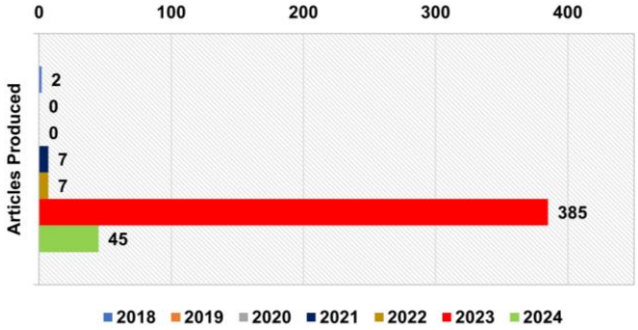


Fig. 3 Annual production of articles in GAI research.

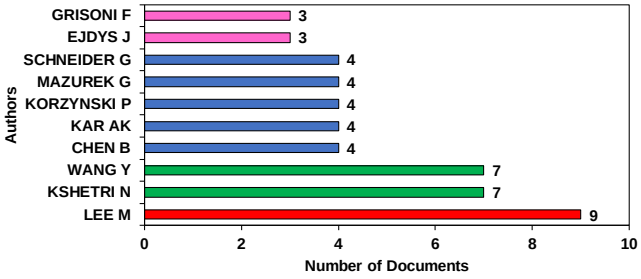


Fig. 4 Top 10 authors in the GAI research domain.

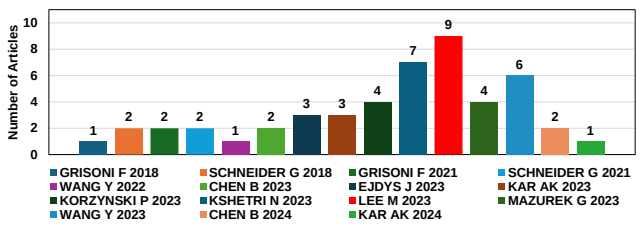


Fig. 5 Number of articles produced by authors over a time.

The authors' local impact based on the h-index and g-index measures is depicted in Fig. 6 and Fig. 7 respectively. Fig. 6, shows that the author "SCHNEIDER G" is at the apex with the h-index measure 4. Fig. 7 shows that the author "KSHETRI N" is at the apex with the g-index measure 7. These h-index and g-index measures showcase the impact of the authors and their quality research work. The higher the index value, the more impact.

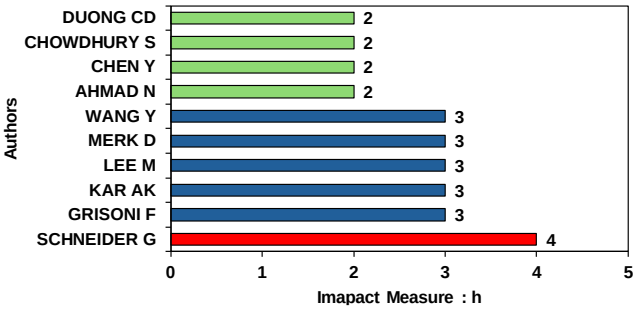


Fig. 6 Authors' local impact (h-index) in GAI research.

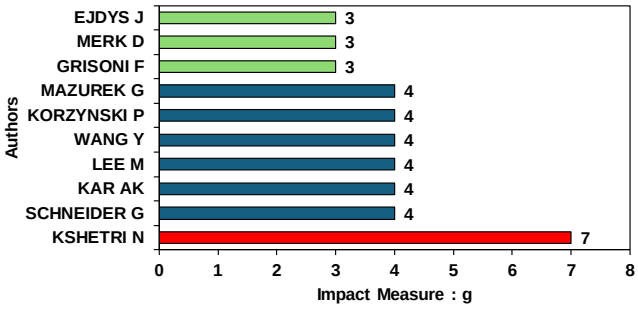


Fig. 7 Authors' local impact (g-index) in GAI research.

The authors' local impact in terms of total citations in the GAI research domain is shown in Fig. 8. In this, the top 10 authors are listed, and it is observed that the author "LIN Z" is in the first position with 600 citations, and the author "SCHNEIDER G" is in the second position with 598 citations. These higher citations represent the impact of these authors with their quality publications in the GAI research domain. The top 10 more relevant sources are shown in Fig. 9 and addressed RQ4. The journals shown in this figure published articles on various applications of GAI and will help the researchers publish their works in highly impactful journals. Among these, the journal "CONTEMPORARY READINGS IN LAW AND SOCIAL JUSTICE" is in the top position with a count of 19 published articles. Further, the journals "ANALYSIS AND METAPHYSICS" and "JOURNAL OF MEDICAL INTERNET RESEARCH" are in the second position with a count of 15 published articles.

The study of the results shown in Fig. 10 sheds light on the influential affiliations that play an important role in GAI research and address RQ5. Among these, the University of Zilina, Chung Ang University, and the University of California, San Francisco make significant contributions. The graph depicting affiliation production over time shows gradual growth from 2021 to 2023, indicating a continued momentum in research activities and collaboration attempts in the GAI space. This trend reflects these affiliations' ongoing dedication and

engagement in expanding the knowledge frontier of GAI. The affiliation production over time is shown in Fig. 11. From this, it is noticed that the highest production level is from the year 2022. The growing importance of GAI has driven all the affiliations to work in this research domain. Among all affiliations, the affiliation "UNIVERSITY OF ZILINA" has the highest production in the year 2023.

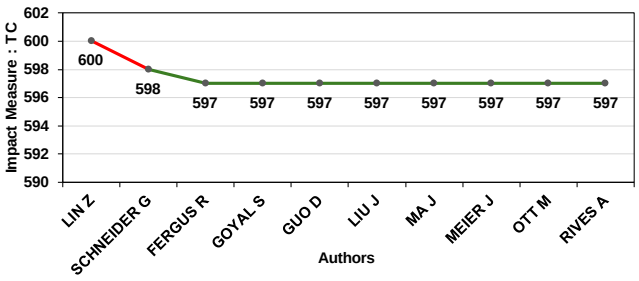


Fig. 8 Authors' local impact (total citations) in the GAI research domain.

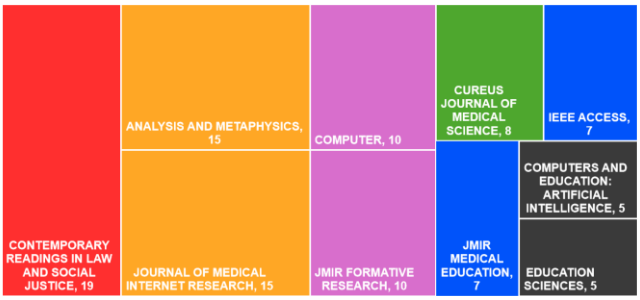


Fig. 9 More relevant sources in the GAI research domain.

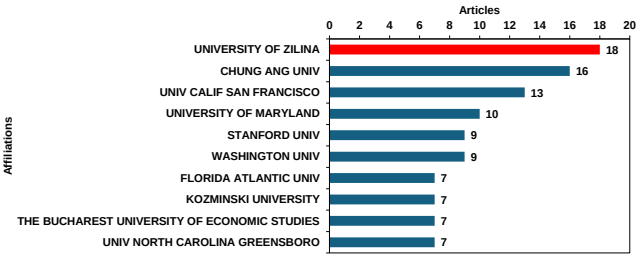


Fig. 10 Top 10 affiliations in the GAI research domain.

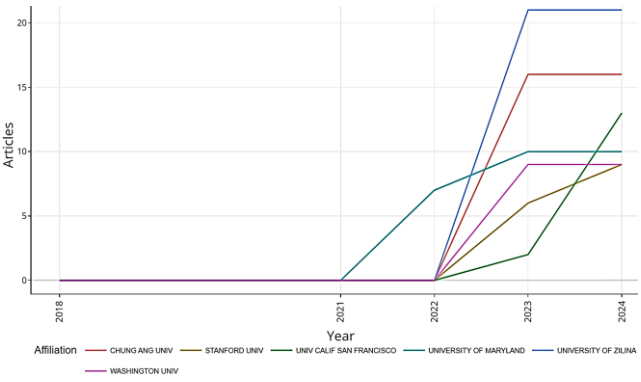


Fig. 11 Affiliation production over time.

The top 10 countries in the production of articles are shown in Fig. 12. Among these. The USA has produced the highest number (304) of articles and the ROMANIA has produced the lowest number (26) of articles. The countries CHINA and the UK occupied the second and third places with the production of articles 85 and 81 respectively. The highest production of articles by the countries represents their active contribution to the GAI research domain.

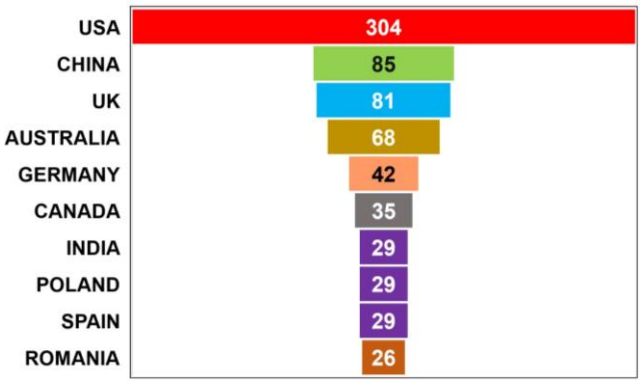


Fig. 12 Country scientific production.

The data shown in Fig. 13 represents the distribution of corresponding authors across various nations, including both multi-country partnerships and single-country publications. Notably, the USA, CHINA, the UNITED KINGDOM, AUSTRALIA, and GERMANY appear as major contributors, with many works by varied authors. This multinational depiction emphasizes the global character of research in GAI. The joint efforts and varying geographical origins of the corresponding authors demonstrate the broad interest and engagement in GAI research, promoting a rich and diversified global discourse on the issue. The majority of multi-country cooperation highlights the collaborative and interrelated character of scientific endeavors in improving knowledge in this area.

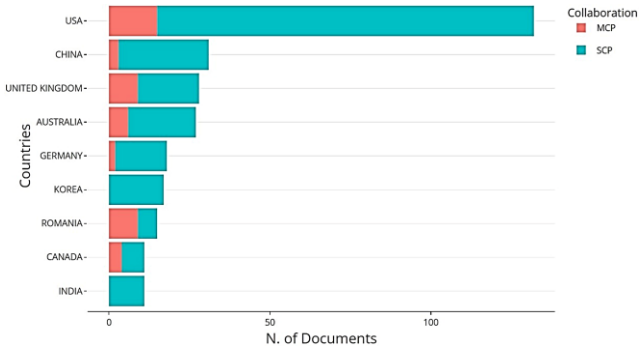


Fig. 13 Corresponding author countries.

The relevance of authors, affiliations, and countries in publishing research works in the GAI domain is shown in Fig. 14. It is a three-field plot, where there are left, middle, and right fields. In this, the left field designates affiliation, the middle field designates the author, and the right field designates the country.

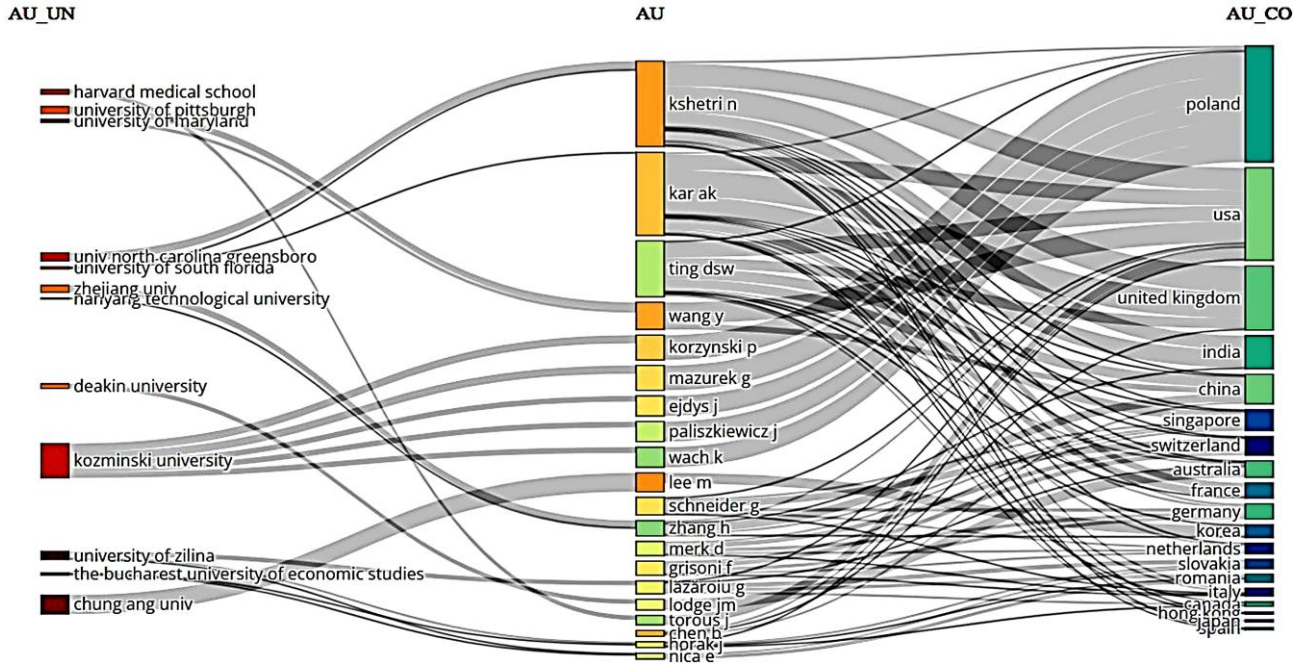


Fig. 14 Relevance of authors, affiliations, and countries.

The top 10 most cited countries in the GAI research domain are shown in Fig. 15 and addressed RQ6. From this, it is noticed that the USA stood at the first position as the highest cited country with citations of 1091 and the AUSTRIA stood at the last position with citations of 48. In the bibliometric analysis of GAI, examining the most cited worldwide publications per total citation shows crucial works that have had a substantial impact on the field. These texts, distinguished by their high citation counts, serve as cornerstone references, demonstrating their widespread effect and respect in the global scholarly community. Exploring these widely referenced documents provides significant insights into seminal contributions, fundamental principles, and long-standing frameworks that have affected the course of GAI research. The highest-cited global documents per citation are shown in Fig. 16 and per year is shown in Fig. 17. From these results, it is noted that the publication "RIVES A, 2021, PROC NATL ACAD SCI USA" is at the top position among the top 10 most-cited global documents and addressed RQ7.

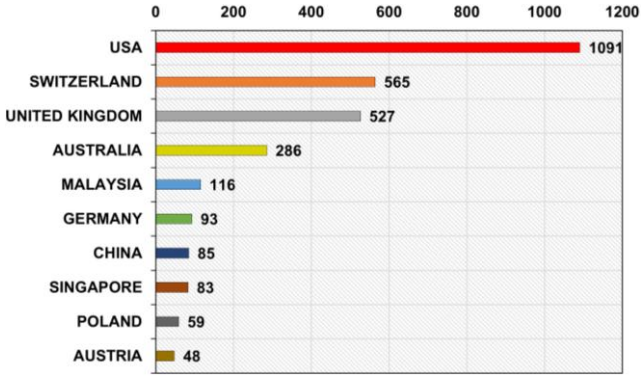


Fig. 15 Most cited countries.

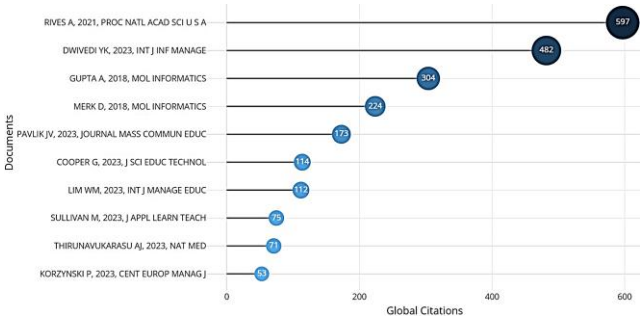


Fig. 16 Most cited global documents per citation.

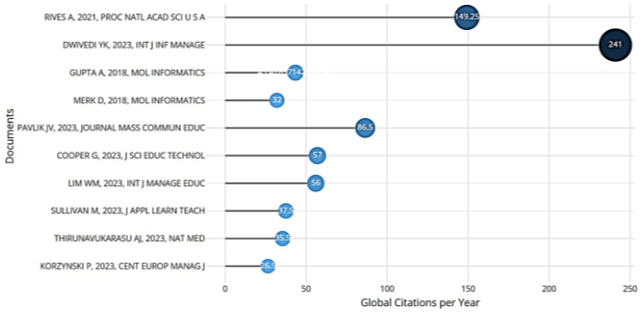


Fig. 17 Most global documents per year.

The analysis of keyword frequency shown in Fig. 18 and Fig. 19 reveals pivotal terms that dominate the discourse around GAI. Notably, keywords such as "chatgpt," "generative artificial intelligence," "artificial intelligence," and "deep learning" emerge as recurrent themes. This observation underscores the central focus and prevalent topics within the field, showcasing the key areas of interest and research. These high-frequency keywords serve as essential pillars, encapsulating the core concepts, technologies, or methodologies that enthusiasts, researchers, and practitioners widely engage with.

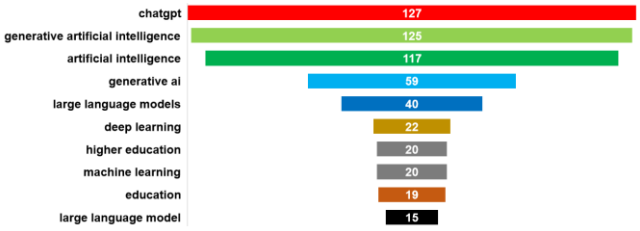


Fig. 18 Most frequent words (author keywords).

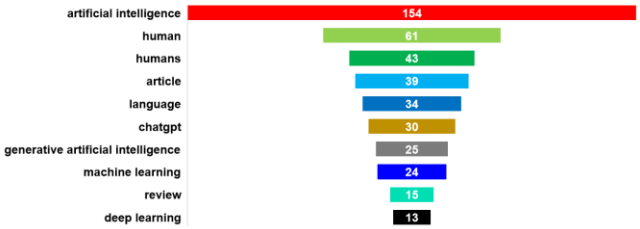


Fig. 19 Most frequent words (keywords plus).

The prominence of these terms signifies their critical role in shaping the narrative and signifies their integral position in the lexicon of GAI, reflecting the community's collective emphasis on these foundational elements. From this, it is observed that the highest-frequency words are ChatGPT and artificial intelligence with frequencies of 127 and 154 respectively.

The evaluation of the results shown in Fig. 20 and Fig. 21 allows us to identify the most common terms used by the writers in GAI research and address RQ8. Notably, keywords like artificial intelligence, ChatGPT, generative artificial intelligence, and large language models appear frequently, emphasizing their importance in literature. The distinction between the most used terms, such as artificial intelligence, human, ChatGPT, and generative AI, and the authors' frequently used keywords demonstrate the field's complex focus and subject diversity. This discovery provides useful insights into the key issues and terminology that writers emphasize in their scholarly contributions, resulting in a more comprehensive grasp of the GAI ecosystem.

Fig. 20 Most frequently used keywords from keywords plus.

Fig. 21 Most frequently used keywords from author keywords.

The collaboration between affiliations, authors, and countries is shown in Fig. 22, Fig. 23, and Fig. 24 respectively. Analyzing these network measures provides useful information on the interconnectedness and influence of each affiliation, author, and country inside the collaborative framework. This extensive examination of collaboration networks provides a sophisticated knowledge of the dynamics and importance of partnerships in the academic landscape. From Fig. 22, it is evident that there is a strong collaboration between the affiliations of “university of zilina”, “university of cralova”, and “the school of expertness and valuation”. The remaining affiliations are having a normal collaboration.

From the research collaboration point of view between authors are summarized and addressed RQ9 as follows:

- From Fig. 23, it is evident that there is a strong collaboration between the authors “korzynski p”, “mazurek g”, and “paliszkiewicz j”. Further, there is a moderate collaboration between the authors “schneider g”, “grisoni f”, and “merk d”. Besides, there is a normal collaboration between the remaining authors in the GAI research domain.

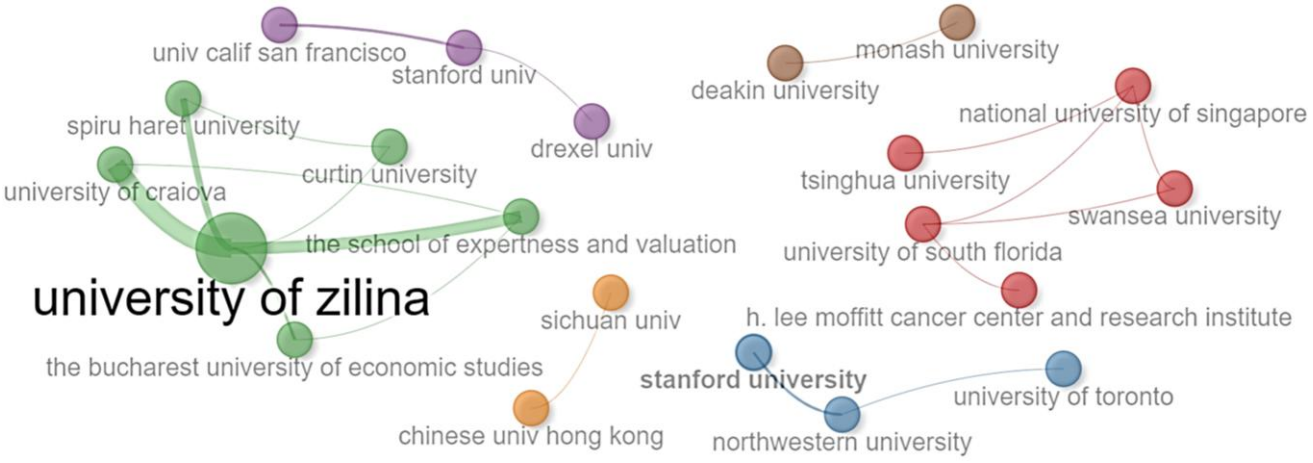


Fig. 22 Affiliation collaboration.

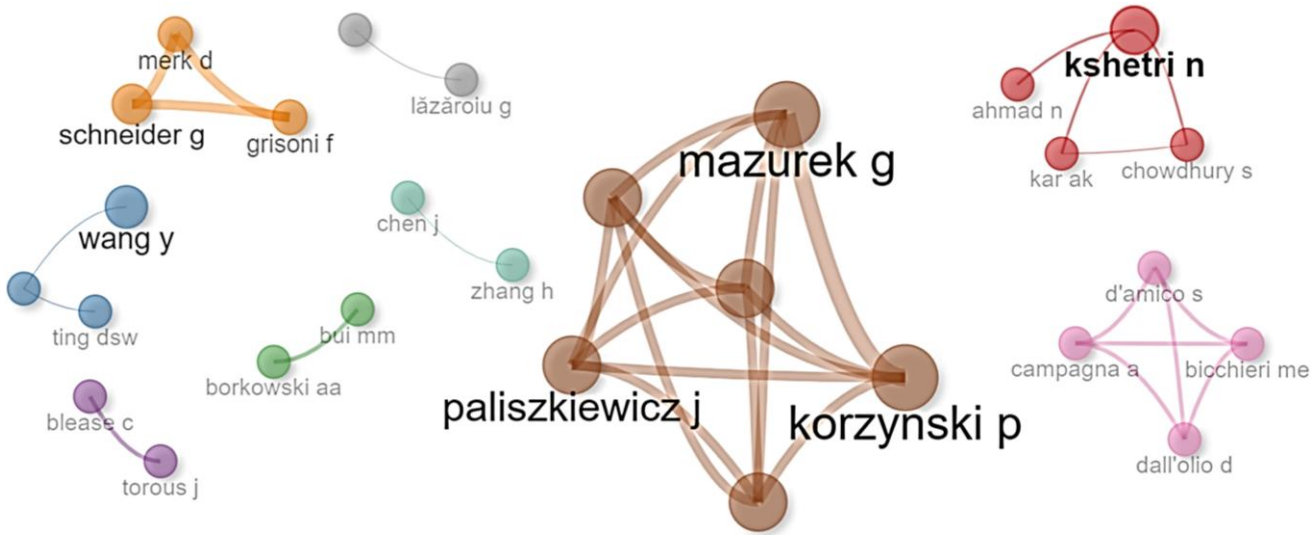
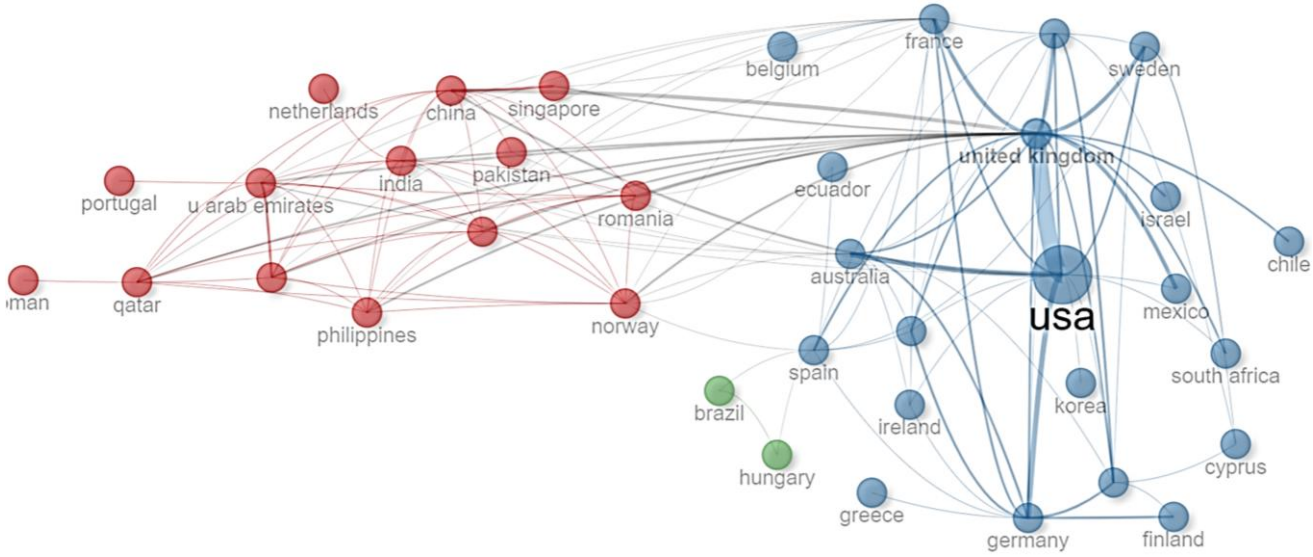
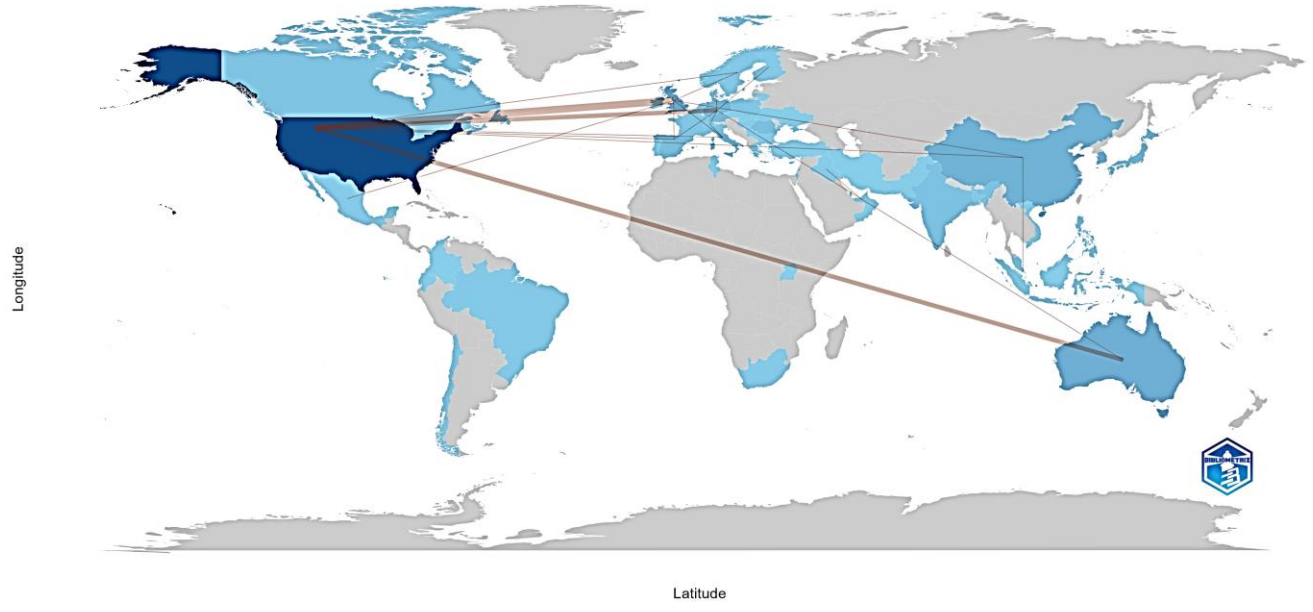


Fig. 23 Authors collaboration.



(a)



(b)

Fig. 24 Country collaboration (a) network (b) map.

From the research collaboration point of view between countries are summarized and addressed RQ10 as follows:

- From Fig. 24(a), it is observed that there is a strong collaboration between the countries “usa and united kingdom”. There is a moderate collaboration between the countries “usa”, “australia”, and “germany”. There is a normal collaboration between the remaining countries.
- Similarly, in Fig. 24(b), the map of countries’ collaboration is presented to quickly grasp the collaboration between countries.

4. Conclusions

The proposed systematic and comprehensive bibliometric analysis has provided key information in various aspects that are beneficial for future researchers of the GAI domain. From the results and discussion, it is found that nowadays most of the articles were published on the GAI domain compared with articles before 2022. Following are the salient observations of this bibliometric analysis.

- Various applications namely neuroimaging, content writing, medical education, deep fake, image generation, physiology, gaming, ethical concern, human resource management, chatbot, prompt engineering, healthcare, economics, education, GAN, security, generative recurrent network, medical chemistry, recurrent neural network, AI, and unsupervised learning are identified.
- It was found that the most frequent keyword used by authors was “artificial intelligence”, “ChatGPT”, “generative ai”, and “large language model”. This suggests that an effective choice of research topics by combining these keywords leads to a faithful result. Moreover, the keyword “chatgpt” is associated with the highest number of titles counted (127) was identified and the keyword “generative artificial intelligence” is associated second highest number of titles counted (125).
- There is a steady increase in the production of papers between 2022 to 2024. In 2023, there is a drastic change in annual production with the highest production of articles (385) found in the year 2023. This shows the rapid growth of GAI in research. Further, most of the research works on GAI are published in WoS and IEEE journals.
- The most relevant authors identified from the analysis are Lee M and Kshetri N. Similarly. The affiliations “University of Zilina” and “Chung Ang University” are identified as the most impactful affiliations with the number of articles. This analysis reveals that the USA and China have occupied the top two positions in producing articles.
- The highest number of single-country publications and the highest number of multiple-country collaborative publications on GAI are from the USA. The second-highest number of single-country publications is from China. The second-highest number of multiple-country collaborative publications is from the United Kingdom. Moreover, the top two positions based on most citations are occupied by the USA and China.

Hence, this bibliometric analysis of GAI helps the researchers to better understand the importance and influence of GAI on various applications, global impact, influential researchers, and research trends, thereby helping them to carry out effective research.

The limitations typical of bibliometric analysis apply to this paper as well. For example, the records analyzed, such as the number of citations, are subject to change over time. However, it is possible to make reasonable predictions about which articles are likely to remain influential in the future. Also, the Scopus and Web of Science databases undergo continuous changes and updates in terms of the number of indexed articles which can influence the analysis. This research includes only recent research studies published between 2013 and 2024 (from the Scopus database).

Future research could expand the time frame to include earlier publications, allowing for a more comprehensive analysis of the evolution of this research. Further, the future direction of this work can be considered from two perspectives.

- Bibliometric perspective: The applications of GAI across various sectors can be explored to assess its potential impact and benefits. For example, investigating the integration of GAI with the Internet of Things could open new research directions and applications.
- Technology perspective: As GAI continues to evolve, there is a growing need for strong ethical guidelines and regulatory frameworks. Future research could focus on developing standardized guidelines to ensure the responsible use of generative AI in various domains.

References

[1] A. Barrett and A. Pack, “Not quite eye to A.I.: student and teacher perspectives on the use of generative artificial intelligence in the writing process,” *Int J Educ Technol High Educ*, vol. 20, no. 1, Art. no. 1, Nov. 2023, doi: https://doi.org/10.1186/s41239-023-00427-0.

[2] P. Zhang and M. N. Kamel Boulos, “Generative AI in Medicine and Healthcare: Promises, Opportunities and Challenges,” *Future Internet*, vol. 15, no. 9, Art. no. 9, Aug. 2023, doi: https://doi.org/10.3390/fi15090286.

[3] A. Banerjee, A. Ahmad, P. Bhalla, and K. Goyal, “Assessing the Efficacy of ChatGPT in Solving Questions Based on the Core Concepts in Physiology,” *Cureus*, Aug. 2023, doi: https://doi.org/10.7759/cureus.43314.

[4] C. Gong *et al.*, “Generative AI for brain image computing and brain network computing: a review,” *Front. Neurosci.*, vol. 17, p. 1203104, Jun. 2023, doi: https://doi.org/10.3389/fnins.2023.1203104.

[5] T. I. Leung, A. Sagar, S. Shroff, and T. L. Henry, "Can AI Mitigate Bias in Writing Letters of Recommendation?," *JMIR Med Educ*, vol. 9, p. e51494, Aug. 2023, doi: https://doi.org/10.2196/51494.

[6] M. M. Shoja, J. M. M. Van De Ridder, and V. Rajput, "The Emerging Role of Generative Artificial Intelligence in Medical Education, Research, and Practice," *Cureus*, Jun. 2023, doi: https://doi.org/10.7759/cureus.40883.

[7] G. Gupta, K. Raja, M. Gupta, T. Jan, S. T. Whiteside, and M. Prasad, "A Comprehensive Review of DeepFake Detection Using Advanced Machine Learning and Fusion Methods," *Electronics*, vol. 13, no. 1, Art. no. 1, Dec. 2023, doi: https://doi.org/10.3390/electronics13010095.

[8] I. M. Tsidylo and E. S. Chele, "Artificial Intelligence As A Methodological Innovation In The Training Of Future Designers: Midjourney Tools," *ITLT*, vol. 97, no. 5, Art. no. 5, Oct. 2023, doi: https://doi.org/10.33407/itlt.v97i5.5338.

[9] K. A. Justs *et al.*, "Mitochondrial phosphagen kinases support the volatile power demands of motor nerve terminals," *The Journal of Physiology*, vol. 601, no. 24, Art. no. 24, Dec. 2023, doi: https://doi.org/10.1113/JP284872.

[10] G. E. Kaebnick *et al.*, "Editors' statement on the responsible use of generative AI technologies in scholarly journal publishing," *Med Health Care and Philos*, vol. 26, no. 4, Art. no. 4, Dec. 2023, doi: https://doi.org/10.1007/s11019-023-10176-6.

[11] M. Agarwal, A. Goswami, and P. Sharma, "Evaluating ChatGPT-3.5 and Claude-2 in Answering and Explaining Conceptual Medical Physiology Multiple-Choice Questions," *Cureus*, Sep. 2023, doi: https://doi.org/10.7759/cureus.46222.

[12] Y. You, Y. Chen, Y. You, Q. Zhang, and Q. Cao, "Evolutionary Game Analysis of Artificial Intelligence Such as the Generative Pre-Trained Transformer in Future Education," *Sustainability*, vol. 15, no. 12, Art. no. 12, Jun. 2023, doi: https://doi.org/10.3390/su15129355.

[13] N. Lucchi, "ChatGPT: A Case Study on Copyright Challenges for Generative Artificial Intelligence Systems," *Eur. j. risk regul.*, pp. 1–23, Aug. 2023, doi: https://doi.org/10.1017/err.2023.59.

[14] B. Lim *et al.*, "Using Generative Artificial Intelligence Tools in Cosmetic Surgery: A Study on Rhinoplasty, Facelifts, and Blepharoplasty Procedures," *JCM*, vol. 12, no. 20, Art. no. 20, Oct. 2023, doi: https://doi.org/10.3390/jcm12206524.

[15] J. Franganillo, "Generative artificial intelligence and its impact on the creation of media content," *m.rcs*, vol. 11, no. 2, Art. no. 2, Sep. 2023, doi: https://doi.org/10.17502/mrcs.v11i2.710.

[16] S. Ali *et al.*, "Children as creators, thinkers and citizens in an AI-driven future," *Computers and Education: Artificial Intelligence*, vol. 2, p. 100040, 2021, doi: https://doi.org/10.1016/j.caeai.2021.100040.

[17] P. Budhwar *et al.*, "Human resource management in the age of generative artificial intelligence: Perspectives and research directions on ChatGPT," *Human Res Mgmt Journal*, vol. 33, no. 3, Art. no. 3, Jul. 2023, doi: https://doi.org/10.1111/1748-8583.12524.

[18] J. Haase and P. H. P. Hanel, "Artificial muses: Generative artificial intelligence chatbots have risen to human-level creativity," *Journal of Creativity*, vol. 33, no. 3, Art. no. 3, Dec. 2023, doi: https://doi.org/10.1016/j.yjoc.2023.100066.

[19] F. E. Babl and M. P. Babl, "Generative artificial intelligence: Can CHATGPT write a quality abstract?," *Emerg Medicine Australasia*, vol. 35, no. 5, Art. no. 5, Oct. 2023, doi: https://doi.org/10.1111/1742-6723.14233.

[20] "ChatGPT in higher education: Considerations for academic integrity and student learning," *JALT*, vol. 6, no. 1, Art. no. 1, Mar. 2023, doi: https://doi.org/10.37074/jalt.2023.6.1.17.

[21] F. French, D. Levi, C. Maczo, A. Simonaityte, S. Triantafyllidis, and G. Varda, "Creative Use of OpenAI in Education: Case Studies from Game Development," *MTI*, vol. 7, no. 8, Art. no. 8, Aug. 2023, doi: https://doi.org/10.3390/mti7080081.

[22] W. Zaitsu and M. Jin, "Distinguishing ChatGPT(-3.5, -4)-generated and human-written papers through Japanese stylometric analysis," *PLoS ONE*, vol. 18, no. 8, Art. no. 8, Aug. 2023, doi: https://doi.org/10.1371/journal.pone.0288453.

[23] P. Korzynski, G. Mazurek, P. Krzypkowska, and A. Kurasinski, "Artificial intelligence prompt engineering as a new digital competence: Analysis of generative AI technologies such as ChatGPT," *EBER*, vol. 11, no. 3, Art. no. 3, 2023, doi: https://doi.org/10.15678/EBER.2023.110302.

[24] T. F. Tan *et al.*, "Generative Artificial Intelligence Through ChatGPT and Other Large Language Models in Ophthalmology," *Ophthalmology Science*, vol. 3, no. 4, Art. no. 4, Dec. 2023, doi: https://doi.org/10.1016/j.xops.2023.100394.

[25] F. M. Megahed, Y.-J. Chen, J. A. Ferris, S. Knoth, and L. A. Jones-Farmer, "How generative AI models such as ChatGPT can be (mis)used in SPC practice, education, and research? An exploratory study," *Quality Engineering*, vol. 36, no. 2, Art. no. 2, Apr. 2024, doi: https://doi.org/10.1080/08982112.2023.2206479.

[26] A. Barcaui and A. Monat, "Who is better in project planning?Generative artificial intelligence or project managers?," *Project Leadership and Society*, vol. 4, p. 100101, Dec. 2023, doi: https://doi.org/10.1016/j.plas.2023.100101.

[27] I. Seth *et al.*, "Utilizing GPT-4 and generative artificial intelligence platforms for surgical education: an experimental study on skin ulcers," *Eur J Plast Surg*, vol. 47, no. 1, Art. no. 1, Jan. 2024, doi: https://doi.org/10.1007/s00238-024-02162-9.

[28] M. Hueso, R. Álvarez, D. Marí, V. Ribas-Ripoll, K. Lekadir, and A. Vellido, "Is generative artificial intelligence the next step toward a personalized hemodialysis?," *RIC*, vol. 75, no. 6, Art. no. 6, Dec. 2023, doi: https://doi.org/10.24875/RIC.23000162.

[29] J. Huang *et al.*, "Generative Artificial Intelligence for Chest Radiograph Interpretation in the Emergency Department," *JAMA Netw Open*, vol. 6, no. 10, Art. no. 10, Oct. 2023, doi: https://doi.org/10.1001/jamanetworkopen.2023.36100.

[30] D. Oniani *et al.*, "Adopting and expanding ethical principles for generative artificial intelligence from military to healthcare," *npj Digit. Med.*, vol. 6, no. 1, Art. no. 1, Dec. 2023, doi: https://doi.org/10.1038/s41746-023-00965-x.

[31] X. Zheng, J. Li, M. Lu, and F.-Y. Wang, "New Paradigm for Economic and Financial Research With Generative AI: Impact and Perspective," *IEEE Trans. Comput. Soc. Syst.*, pp. 1–11, 2024, doi: https://doi.org/10.1109/TCSS.2023.3334306.

[32] R. W. Qu, U. Qureshi, G. Petersen, and S. C. Lee, "Diagnostic and Management Applications of ChatGPT in Structured Otolaryngology Clinical Scenarios," *OTO Open*, vol. 7, no. 3, Art. no. 3, Jul. 2023, doi: https://doi.org/10.1002/oto2.67.

[33] C. Davila *et al.*, "Online Forums as a Tool for Broader Inclusion of Voices on Health Care Communication Experiences and Serious Illness Care: Mixed Methods Study," *J Med Internet Res*, vol. 25, p. e48550, Dec. 2023, doi: https://doi.org/10.2196/48550.

[34] D. Najafali *et al.*, "Bard Versus the 2022 American Society of Plastic Surgeons In-Service Examination: Performance on the Examination in Its Intern Year," *Aesthetic Surgery Journal Open Forum*, vol. 6, p. ojad066, Jan. 2024, doi: https://doi.org/10.1093/asjof/ojad066.

[35] K. Ali, N. Barhom, F. Tamimi, and M. Duggal, "ChatGPT—A double-edged sword for healthcare education? Implications for assessments of dental students," *Eur J Dental Education*, vol. 28, no. 1, Art. no. 1, Feb. 2024, doi: https://doi.org/10.1111/eje.12937.

[36] T. Lancaster, "Artificial intelligence, text generation tools and ChatGPT – does digital watermarking offer a solution?," *Int J Educ Integr*, vol. 19, no. 1, Art. no. 1, Jun. 2023, doi: https://doi.org/10.1007/s40979-023-00131-6.

[37] X. Zhai, M. Nyaaba, and W. Ma, "Can Generative AI and ChatGPT Outperform Humans on Cognitive-Demanding Problem-Solving Tasks in Science?," *Sci & Educ*, Jan. 2024, doi: https://doi.org/10.1007/s11191-024-00496-1.

[38] R. Michel-Villarreal, E. Vilalta-Perdomo, D. E. Salinas-Navarro, R. Thierry-Aguilera, and F. S. Gerardou, "Challenges and Opportunities of Generative AI for Higher Education as Explained by ChatGPT," *Education Sciences*, vol. 13, no. 9, Art. no. 9, Aug. 2023, doi: https://doi.org/10.3390/educsci13090856.

[39] T. Farrelly and N. Baker, "Generative Artificial Intelligence: Implications and Considerations for Higher Education Practice," *Education Sciences*, vol. 13, no. 11, Art. no. 11, Nov. 2023, doi: https://doi.org/10.3390/educsci13111109.

[40] O. V. Spivakovsky, S. A. Omelchuk, V. V. Kobets, N. V. Valko, and D. S. Malchykova, "Institutional Policies On Artificial Intelligence In University Learning, Teaching And Research," *ITLT*, vol. 97, no. 5, Art. no. 5, Oct. 2023, doi: https://doi.org/10.33407/itlt.v97i5.5395.

[41] N. Pellas, "The Effects of Generative AI Platforms on Undergraduates' Narrative Intelligence and Writing Self-Efficacy," *Education Sciences*, vol. 13, no. 11, Art. no. 11, Nov. 2023, doi: https://doi.org/10.3390/educsci13111155.

[42] W. Zha, X. Li, D. Li, Y. Xing, L. He, and J. Tan, "Shale Digital Core Image Generation Based on Generative Adversarial Networks," *Journal of Energy Resources Technology*, vol. 143, no. 3, Art. no. 3, Mar. 2021, doi: https://doi.org/10.1115/1.4048052.

[43] K. G. Liakos, G. K. Georgakilas, F. C. Plessas, and P. Kitsos, "GAINESIS: Generative Artificial Intelligence NEtlists SynthesIS," *Electronics*, vol. 11, no. 2, Art. no. 2, Jan. 2022, doi: https://doi.org/10.3390/electronics11020245.

[44] A. Gupta, A. T. Müller, B. J. H. Huisman, J. A. Fuchs, P. Schneider, and G. Schneider, "Generative Recurrent Networks for *De Novo* Drug Design," *Molecular Informatics*, vol. 37, no. 1–2, Art. no. 1–2, Jan. 2018, doi: https://doi.org/10.1002/minf.201700111.

[45] K. J. Schultz, S. M. Colby, Y. Yesiltepe, J. R. Nuñez, M. Y. McGrady, and R. S. Renslow, "Application and assessment of deep learning for the generation of potential NMDA receptor antagonists," *Phys. Chem. Chem. Phys.*, vol. 23, no. 2, Art. no. 2, 2021, doi: https://doi.org/10.1039/D0CP03620J.

[46] D. Merk, L. Friedrich, F. Grisoni, and G. Schneider, "*De Novo* Design of Bioactive Small Molecules by Artificial Intelligence," *Molecular Informatics*, vol. 37, no. 1–2, Art. no. 1–2, Jan. 2018, doi: https://doi.org/10.1002/minf.201700153.

[47] S.-T. Tsai, E. Fields, Y. Xu, E.-J. Kuo, and P. Tiwary, "Path sampling of recurrent neural networks by incorporating known physics," *Nat Commun*, vol. 13, no. 1, Art. no. 1, Nov. 2022, doi: https://doi.org/10.1038/s41467-022-34780-x.

[48] J. Lötsch, A. Ultsch, B. Mayer, and D. Kringel, "Artificial intelligence and machine learning in pain research: a data scientometric analysis," *PR9*, vol. 7, no. 6, Art. no. 6, Nov. 2022, doi: https://doi.org/10.1097/PR9.0000000000001044.

[49] A. Rives *et al.*, "Biological structure and function emerge from scaling unsupervised learning to 250 million protein sequences," *Proc. Natl. Acad. Sci. U.S.A.*, vol. 118, no. 15, Art. no. 15, Apr. 2021, doi: https://doi.org/10.1073/pnas.2016239118.

[50] A. A. Khan, R. K. Mahendran, K. Perumal, and M. Faheem, "Dual-3DM ^{3} -AD: Mixed Transformer based Semantic Segmentation and Triplet Pre-processing for Early Multi-Class Alzheimer's Diagnosis," *IEEE Trans. Neural Syst. Rehabil. Eng.*, pp. 1–1, 2024, doi: https://doi.org/10.1109/TNSRE.2024.3357723.

[51] A. Alqarafi, A. Ahmad Khan, R. Kumar Mahendran, M. Al-Sarem, and F. Albalwy, "Multi-scale GC-T2: Automated region of interest assisted skin cancer detection using multi-scale graph convolution and tri-movement based attention mechanism," *Biomedical Signal Processing and Control*, vol. 95, p. 106313, Sep. 2024, doi: https://doi.org/10.1016/j.bspc.2024.106313.

[52] J. N. Cheltha, C. Sharma, D. Prashar, A. A. Khan, and S. Kadry, "Enhanced human motion detection with hybrid RDA-WOA-based RNN and multiple hypothesis tracking for occlusion handling," *Image and Vision Computing*, vol. 150, p. 105234, Oct. 2024, doi: https://doi.org/10.1016/j.imavis.2024.105234.

[53] A. A. Khan, R. K. Madendran, U. Thirunavukkarasu, and M. Faheem, "D^2PAM: Epileptic seizures prediction using adversarial deep dual patch attention mechanism," *CAAI Trans on Intel Tech*, vol. 8, no. 3, pp. 755–769, Sep. 2023, doi: https://doi.org/10.1049/cit2.12261.

[54] A. Ahmad Khan *et al.*, "Detection of Omicron Caused Pneumonia from Radiology Images Using Convolution Neural Network (CNN)," *Computers, Materials & Continua*, vol. 74, no. 2, pp. 3743–3761, 2023, doi: https://doi.org/10.32604/cmc.2023.033924.

[55] H. Kasaraneni and S. Rosaline, "Automatic Merging of Scopus and Web of Science Data for Simplified and Effective Bibliometric Analysis," *Ann. Data. Sci.*, Aug. 2022, doi: https://doi.org/10.1007/s40745-022-00438-0.