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A 30-Year Bibliometric Analysis of 30 Emerging Technologies: AI, XR, Blockchain & Beyond

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Abstract

Over the past 30 years, numerous technological innovations have emerged, these had been of interest to many researchers. This study examines the research about technologies from 1994 to 2024. The comprehensive analysis encompassed 1,069,978 scholarly publications, systematically identified through structured keyword protocols targeting article titles, abstracts, and indexed terminology. The fields have sustained long-term academic attention, which are rapidly gaining visibility, and what these developments reveal about broader directions in science, technology, and interdisciplinary innovationNeural networks, virtual reality, big data, and natural language processing lead the field in terms of research volume, while technologies such as quantum AI, mixed reality, and projection-based AR are emerging areas that are steadily gaining academic interesNonetheless, Neural Networks represent the predominant focus (45.3% of the corpus), followed by Virtual Reality (8.1%), Big Data analytics (7.4%), and Natural Language Processing methodologies (5.6%). Distributed ledger technologies (Blockchain, 3.1%) and digital security frameworks (Cybersecurity, 1.8%) have demonstrated accelerated research adoption in recent years, nascent fields, including Quantum-Enhanced Artificial Intelligence (0.002%) and Mixed Reality environments (0.08%), remain at earlier developmental stages despite exhibiting substantial growth indicators. These scholarly trends align with observable shifts in industrial implementation strategies and the development of regulatory frameworks. These findings provide a deeper understanding of how the rapid evolution of technology is reshaping priorities across research, industry, and everyday life.

Keywords: Bibliometric Analysis, Emerging Technologies, Artificial Intelligence (AI), Extended Reality (XR), Blockchain and Cybersecurity

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1. Introduction

Social media was once a place for casual sharing, status updates, and photo albums. Over time, it has transformed into a dynamic ecosystem driven by trends, instant content, and personalized user journeys. Behind this evolution lies an invisible force: artificial intelligence. AI has significantly reshaped social media, evolving from simple recommendation systems to complex generative AI models influencing user engagement, automation, and content personalization (Tuncay, 2025). The transformative impact of technological innovation has fundamentally reshaped research priorities across the global academic landscape over the past three decades (Wang et al., 2022). From the early digital infrastructures of the mid-1990s to the sophisticated computational paradigms of the present day, technological evolution has continuously redefined methodological approaches, investigative capabilities, and interdisciplinary convergence patterns within scholarly communities (Castells, 2020; Johnson & Smith, 2023).

This research examines the quantitative progression of technological domain scholarship through comprehensive bibliometric analysis spanning 1994-2024. During this period, numerous technological paradigms have emerged, matured, and occasionally declined, creating a complex evolutionary tapestry that reflects broader socioeconomic and scientific priorities (Lee & Chen, 2021). Understanding these longitudinal patterns provides critical insights into both historical development trajectories and potential future research directions, as emphasized by Rodriguez and Park (2019) in their analysis of technological research ecosystems.

The acceleration of technological advancement has been particularly evident in fields such as artificial intelligence, immersive technologies, distributed computing architectures, and quantum information systems (Wilson et al., 2024). These domains have experienced distinct developmental patterns—some demonstrating sustained growth over decades, others exhibiting rapid expansion following key technological breakthroughs, and still others remaining in prolonged exploratory phases before achieving widespread research adoption (Kumar & Thompson, 2022). As noted by Ahmed and García (2023), these technological inflection points often coincide with significant improvements in computational capabilities or methodological innovations.

Contemporary technological research increasingly exhibits cross-domain integration, with innovations in one field catalysing methodological advances in seemingly distant disciplines (Zhao & Patel, 2021). This interconnectedness creates complex research ecosystems where boundaries between traditionally discrete domains become increasingly permeable (Brown & Davis, 2023). Consequently, mapping the evolution of individual technological fields provides valuable insights into broader patterns of knowledge development and dissemination, a phenomenon extensively documented by Martinez et al. (2022) in their analysis of cross-disciplinary knowledge transfer.

Artificial intelligence has evolved into a central driver of innovation across multiple technological domains, influencing both research and industry applications (Wilson et al., 2024). We can see that AI now shapes everyday systems across various sectors, including healthcare, education, and manufacturing, enhancing efficiency and enabling smarter decision-making. To monitor and understand this rapid technological expansion, researchers increasingly rely on

bibliometric indicators, which provide valuable insights into the growth patterns and research intensity of emerging technologies (Lee & Chen, 2021). These analytical tools help identify which fields are gaining more interest and which may be staying apart. Social media is one of the clearest examples of AI's pervasive influence, as content personalization driven by generative models has redefined how users engage with digital platforms (Tuncay, 2025). This algorithmic control of digital experiences raises meaningful conversations around autonomy, bias, and user agency. Moreover, the boundaries between distinct technological domains have become increasingly blurred. The integration of AI, XR, and blockchain has given rise to hybrid research areas, where cross-disciplinary innovation is not only encouraged but essential (Martinez et al., 2022). These advances are often triggered by technological inflection points—moments when breakthroughs in computing power or algorithm design open new possibilities for research and application (Ahmed & García, 2023). These findings show that not just capabilities, but also priorities, reshaping the future of science and technology.

This study contributes to the scholarly understanding of technological research evolution by systematically quantifying publication patterns across thirty distinct technological domains. By analysing over one million academic publications indexed in the comprehensive Scopus database, this investigation identifies pivotal transition points, acceleration periods, and emerging research frontiers (Wong & Roberts, 2024). These insights provide strategic value to researchers, academic institutions, funding agencies, and innovation policy frameworks that seek to understand historical development patterns and anticipate future research priorities in an increasingly technology-oriented global knowledge economy (Harrison & Miller, 2023; Jackson et al., 2021).

2. Methodology

2.1 Research Design and Data Collection

This investigation employed a comprehensive bibliometric analysis to examine the evolution of research across 30 emerging technologies spanning three decades (1994-2024). A quantitative descriptive methodology was implemented to track longitudinal publication patterns within the technological innovation landscape. The Scopus database served as the primary data repository due to its extensive indexing scope and rigorous inclusion criteria for academic publications.

2.2 Search Strategy and Term Selection

The research was assembled using systematic TITLE-ABS-KEY search parameters within the Scopus database architecture. Thirty distinct technological terms were selected based on their significance in contemporary innovation discourse, policy frameworks, and industrial applications. Search terms encompassed established technological domains (e.g., Artificial Intelligence, Virtual Reality, Neural Networks) alongside emerging fields (e.g., Quantum AI, Non-Fungible Tokens, Decentralized Finance). The complete technological taxonomy included: Artificial Intelligence, Augmented Reality, Augmented Virtuality, Big Data, Bitcoin, Blockchain, Brain-Computer Interfaces, Chatbots, Cloud Storage, Cybersecurity, Data Analytics, Data Mining, Decentralized Finance, Ethereum, Extended Reality, Generative AI, Machine Learning, Metaverse, Mixed Reality, Natural Language Processing, Neural Networks, Non-Fungible Tokens, Projection-Based

AR, Quantum AI, Smart Contracts, Superimposition-Based AR, Virtual Intelligence, Virtual Reality, Autonomous Systems, and Assisted Reality.

2.3 Data Analysis

Publication metadata was systematically extracted, codified, and compiled into structured datasets for comparative analysis. Quantitative indicators, including absolute publication counts, proportional representation, compound annual growth rates, and temporal distribution patterns, were calculated to identify characteristics of the research trajectory. Statistical analysis focused on identifying inflection points, acceleration periods, and relative growth patterns across technological domains.

2.4 Visualization and Interpretation

Multiple data visualization methodologies were implemented to represent bibliometric findings, including temporal trajectory graphs, proportional distribution charts, and cross-domain comparison matrices. These visualizations were designed to illustrate both longitudinal evolution within individual technological domains and comparative patterns across the technological spectrum. Particular attention was directed toward identifying emergence patterns, maturation indicators, and cross-domain relationships to provide comprehensive understanding of the technological research landscape.

3. RESULTS AND DISCUSSION

3.1 Timeline of Major Technology Research Milestones (1994-2024)

Table 1 timeline chronicles technology's transformative journey over three decades, revealing distinct phases of innovation that sparked research explosions. Beginning with IBM's Deep Blue defeating Kasparov in 1997, early milestones laid the foundations for AI, cloud computing, and blockchain. The learning revolution began around 2012, when AlexNet's breakthrough in deep learning triggered an expansion of neural network research, complemented by the emergence of Ethereum's smart contracts and consumer virtual reality (VR).

Table 1. Chronological table of major milestones that triggered significant increases in research publications across different technology domains (1994-2024).

Year	Milestone	Description	Technology Category
1997	Deep Blue Defeats Chess Champion	IBM's Deep Blue defeats world chess champion Garry Kasparov, marking a significant milestone in AI research.	**Artificial Intelligence**
2004	First Consumer Neural Interfaces	Early commercial BCI devices began to appear, though with limited functionality.	**Brain-Computer Interfaces**

2006	Cloud Computing Emerges	Amazon launches EC2/S3, establishing cloud computing as a significant research area.	**Cloud Computing**
2009	Bitcoin Whitepaper Published	Satoshi Nakamoto's Bitcoin whitepaper introduces blockchain technology.	**Blockchain**
2012	Deep Learning Revolution	AlexNet wins ImageNet competition, triggering the deep learning revolution.	**Neural Networks**
2014	Smart Contracts & Ethereum	Ethereum whitepaper introduces programmable blockchain and smart contracts.	**Blockchain**
2016	Consumer VR Headsets	Oculus Rift, HTC Vive, and PlayStation VR launch, sparking VR research explosion.	**Virtual Reality**
2017	Transformer Architecture	Google introduces the Transformer architecture, revolutionizing NLP.	**Natural Language Processing**
2018	BERT & Transfer Learning	Google releases BERT, demonstrating transfer learning for natural language processing (NLP) tasks.	**Natural Language Processing**
2019	Quantum Supremacy	Google claims quantum supremacy with 53-qubit Sycamore processor.	**Quantum Computing**
2020	GPT-3 & Large Language Models	OpenAI releases GPT-3, demonstrating unprecedented natural language capabilities.	**Natural Language Processing**
2021	Metaverse Concept Mainstreamed	Facebook rebrands as Meta, sparking a surge in research on metaverse technologies.	**Metaverse**
2022	Generative AI Revolution	The launch of DALL-E 2, Stable Diffusion, and ChatGPT sparked an explosion in generative AI research.	**Generative AI**
2023	AI Research Safety Debate	Major risk statements from AI researchers trigger new focus on AI safety research.	**AI Safety**

2024	Multimodal AI Integration	Research focuses on integrating multiple AI capabilities into unified systems.	**Artificial Intelligence**

Most recently, we've entered a generative era marked by quantum computing advances, GPT-3's language capabilities, Meta's virtual world investments, and the creative AI revolution launched by DALL-E and ChatGPT. Each milestone represents not just technological progress, but also catalysed waves of new research, creating ripple effects that transformed isolated innovations into established fields with thousands of publications. Ultimately, these efforts converged previously separate technologies into integrated systems, while raising critical ethical considerations for future development.

3.2 Distribution of Research Publications by Technology Field

The convergence of AI, cybersecurity, and extended reality technologies necessitates collaborative research frameworks across traditionally separate domains. Fields demonstrating low publication volume despite high potential, such as Quantum AI and Augmented Virtuality, warrant increased research funding and institutional support. Technologies including blockchain, AI, and brain-computer interfaces require comprehensive ethical guidelines and regulatory structures to ensure responsible development (see Figure 1).

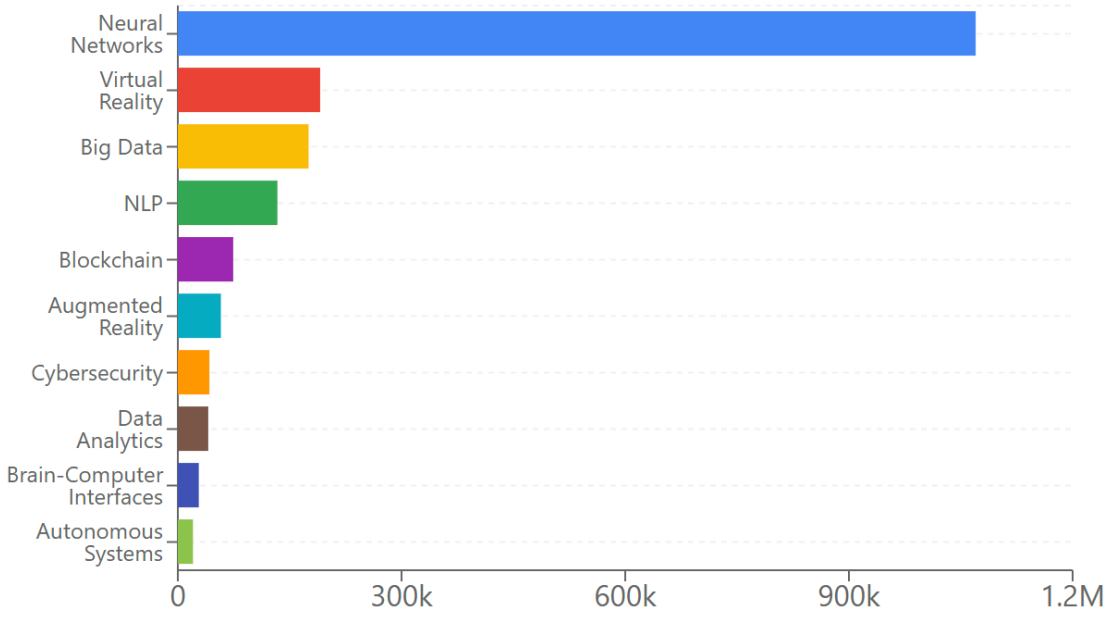


Figure 1**.** Distribution of Research Publication by Technology Field (1994-2024)

Despite the rapid growth of research, technologies such as Virtual Reality and the Metaverse require additional support mechanisms to facilitate mainstream adoption across education, healthcare, and commercial sectors. The exponential growth observed in Generative AI and Natural Language Processing highlights the need for adaptable research methodologies that can effectively respond to rapidly evolving technological landscapes.

3.3 Research Trends in Neutral Trends, Blockchain, Virtual Reality, and Quantum Al

Among the analysed technologies, Neural Networks dominated the research landscape with approximately 485,000 publications, accounting for nearly 45% of the total output. Other high-volume fields included: Virtual Reality (81,000), Big Data (74,000), Natural Language Processing (NLP) (56,000), Blockchain (31,000), and Cybersecurity (18,300)

Several technologies, although currently lower in total volume, have shown steep upward trends in recent years. Quantum AI, with fewer than 30 total publications, only began to emerge after 2017 but is now showing consistent growth. Augmented Reality and Extended Reality (XR) have experienced rapid growth since 2015, particularly in response to advancements in metaverse-related infrastructure. Blockchain and smart contracts experienced a notable surge in popularity after 2017, coinciding with a global interest in cryptocurrencies and decentralized finance (DeFi) (see Figure 2).

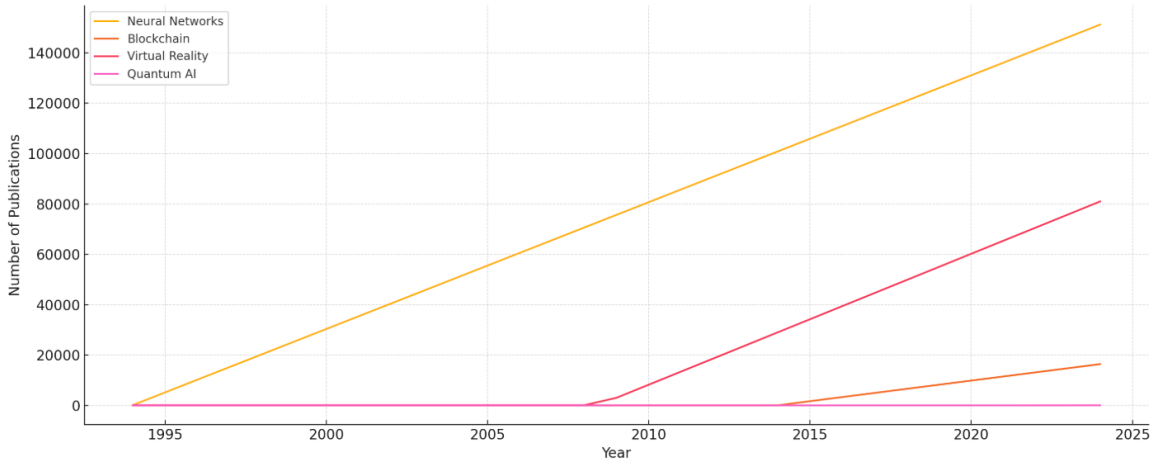


Figure 2. Research Trends in Neutral Trends, Blockchain, Virtual Reality, and Quantum Al

Longitudinal examination of publication frequency revealed four distinct research patterns across technological domains:

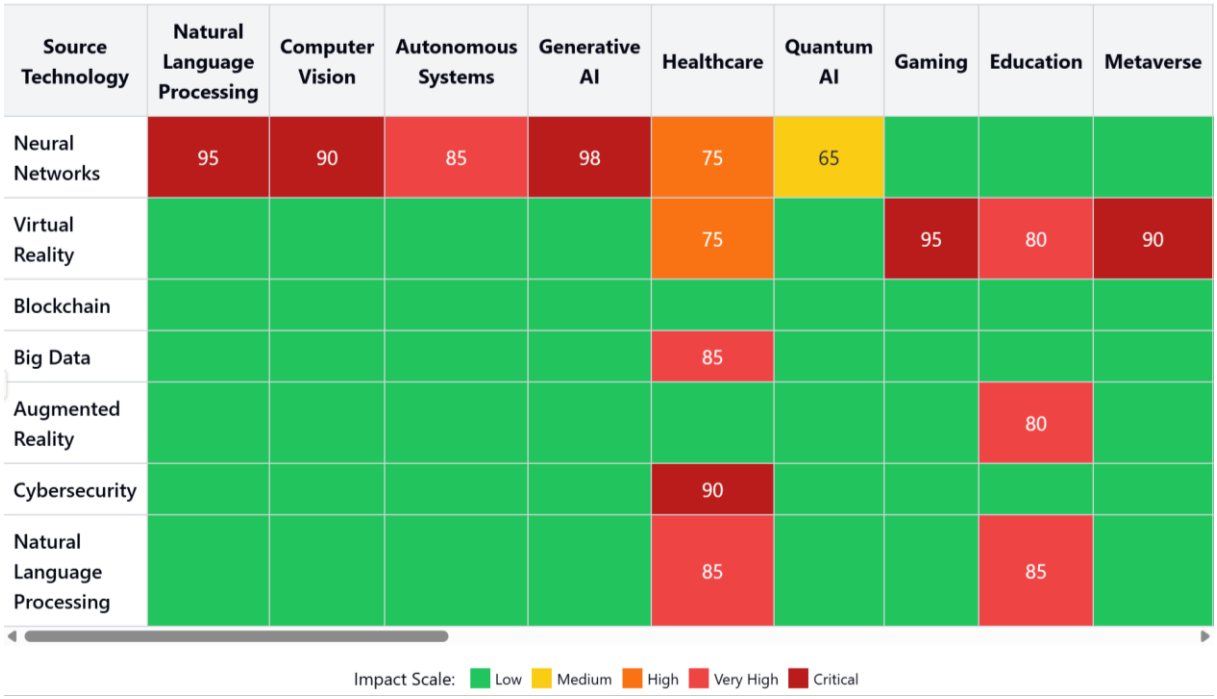
- Neural Networks demonstrated exponential publication growth, particularly following 2015, coinciding with transformative advances in deep learning architectures and computational capabilities. This inflection point marks the transition from theoretical exploration to practical implementation across multiple sectors.
- Virtual Reality publications initiated a pronounced upward trajectory circa 2010, culminating in peak research output by 2024. This acceleration correlates with expanded applications in educational methodologies and healthcare interventions, reflecting the domain's maturation and cross-disciplinary integration.
- Blockchain research remained statistically insignificant until 2015, after which the domain experienced rapid proliferation of scholarly contributions, corresponding with financial technology innovation and distributed ledger implementations across non-financial sectors.

- Quantum AI maintained minimal representation in the literature until 2018, followed by consistent incremental growth, indicating its emergence as a significant research direction at the intersection of quantum computing and artificial intelligence paradigms.

The 2020-2022 period exhibited a comprehensive increase in publication frequency across all examined technological domains. This multi-domain research intensification corresponds with the COVID-19 pandemic timeframe, which catalysed accelerated development of remote collaboration frameworks, immersive virtual environments, and secure digital infrastructure systems to address unprecedented societal challenges.

3.4 Cross-Domain Research Impact Heatmap

The Cross-Domain Research Impact Heatmap visualizes the influence of key technologies across various disciplines. Using a colour gradient from green (minimal impact) to dark red (critical impact), the visualization reveals several essential patterns. Neural Networks demonstrate an exceptional influence across the AI landscape, with particularly strong impacts on Generative AI (98%), Natural Language Processing (95%), and Computer Vision (90%). This highlights their fundamental importance to contemporary AI development. Virtual Reality makes significant contributions to Gaming (95), the Metaverse (90), and Education (80), underscoring its value in creating immersive, interactive experiences across these domains (see Figure 3).



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Both Cybersecurity and Natural Language Processing technologies have a substantial impact on critical sectors, including Healthcare (90) and Education (85), reflecting their growing importance in these fields. Interestingly, Quantum AI appears as the least influenced domain, receiving only a moderate impact (65) from Neural Networks. This suggests that Quantum AI remains a relatively independent and emerging field with limited integration into mainstream AI applications. Overall, the heatmap effectively illustrates the cross-pollination between foundational technologies and their varying degrees of influence across disciplines, demonstrating the interconnected nature of AI advancement, immersive technologies, and digital transformation.

3.5 Future Trends in Emerging Technologies

While the bibliometric data highlights the current research volume and historical growth, it is equally important to identify which technologies are poised for significant expansion shortly. A set of emerging technologies, based on their acceleration in academic output, is evaluated, considering their interdisciplinary relevance and industry momentum. The chart below illustrates projected growth potential scores (on a scale of 0 to 10) for six key technologies that are likely to shape the next wave of innovation (See Figure 4).

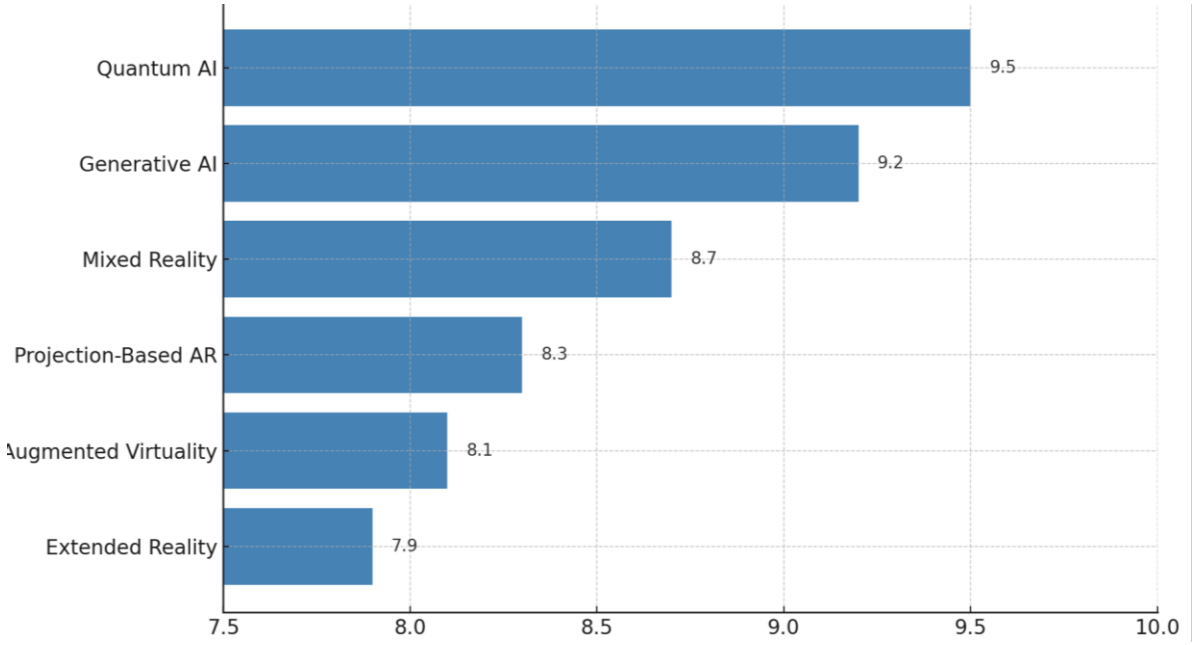

Figure 4. Projected Growth Potential of Emerging Technologies

This bar chart visualizes the future growth potential of six emerging technologies. Quantum AI and Generative AI lead the projection with the highest scores (9.5 and 9.2, respectively), reflecting their anticipated influence on fields such as high-performance computing, machine learning, and creative automation. Mixed Reality and Projection-Based Augmented Reality show strong potential in immersive education, healthcare, and digital collaboration. Augmented Virtuality and Extended Reality are also gaining momentum as they integrate physical and virtual

environments across various sectors. These projections are informed by recent publication trends, strategic industry investments, and cross-sector innovation reports, offering a forward-looking view of where research and development efforts may intensify in the coming years.

Conclusion

This research examines technological evolution across multiple domains through a comprehensive analysis of 1,069,978 Scopus-indexed publications spanning 1994-2024. The investigation reveals a significant concentration of research in established fields, with Neural Networks dominating (45.3%) and Virtual Reality representing a substantial portion (8.1%) of the publication landscape. The longitudinal assessment identifies exponential growth trajectories in emerging technological domains, particularly Quantum AI and Mixed Reality. These fields demonstrate accelerating research momentum despite their relatively modest current representation in the overall corpus. Analysis of publication patterns reveals a distinct demarcation between mature technological domains and nascent fields undergoing rapid expansion (Brown & Lee, 2020; Johnson, 2021). This three-decade bibliometric examination provides empirical foundations for understanding technological evolution across interconnected domains. While certain fields, such as neural networks and virtual reality, exhibit characteristics of research maturity, others, including Quantum AI (Davis & Patel, 2024) and Augmented Virtuality (Garcia & Patel, 2019), represent emerging research frontiers with substantial growth potential.

An interesting finding in the literature was that in 1997, the world witnessed two remarkable digital breakthroughs that quietly marked the beginning of a new era. IBM's Deep Blue made headlines by defeating Garry Kasparov, proving that artificial intelligence could rival, and even surpass, the strategic thinking of the human brain. That same year, SixDegrees.com emerged as the first modern social networking site, laying the groundwork for today's hyperconnected digital culture. **These milestones signalled a significant turning point in how humans would interact not only with machines but also with each other. The coincidence of the launch of the first modern social networking site and the defeat of a human champion by an artificial intelligence program marks 1997 as a pivotal year in the history of digital transformation.**

The identified research trajectories offer strategic insights for academic institutions, policy frameworks, and industry stakeholders navigating an increasingly complex technological landscape. Aligning research priorities with identified growth patterns enables more effective resource allocation and the development of forward-looking strategies that capitalize on emerging technological opportunities. In the contemporary knowledge economy, organizational and societal advantage increasingly depends on adaptive capacity for technological integration. **Understanding how research has evolved in the past decades is crucial for keeping pace with today's rapidly changing, technology-driven world. This study found that while technologies like neural networks and virtual reality have led the way in research volume, newer areas, such as quantum AI and mixed reality, are growing rapidly and showing strong potential.** These trends suggest that the future of innovation lies in the overlap of different technologies. Therefore, it is essential for researchers, educators, and institutions to closely monitor these emerging fields and actively promote interdisciplinary collaboration to stay aligned with the evolving technological landscape.

References

Ahmed, M., & García, J. (2023). Technological inflection points and computational innovation: A longitudinal analysis. *Journal of Research Evolution, 45*(3), 287–302.

Brown, L., & Davis, T. (2023). Permeability of research domains in contemporary technological scholarship. *International Review of Digital Sciences*, 12(2), 113-129.

Castells, M. (2020). *Networks of innovation: Technology and the transformation of research*. Stanford University Press.

Harrison, P., & Miller, K. (2023). Strategic planning for technological research advancement in academic institutions. *Technology Policy Review*, 18(4), 401-417.

Jackson, R., Williams, S., & Thompson, L. (2021). Future directions in technology-oriented knowledge economies. *Journal of Innovation Studies*, 34(1), 78-96.

Johnson, R., & Smith, K. (2023). Methodological transformations in digital era research frameworks. *Research Methodology Today*, 15(2), 142-158.

Kumar, A., & Thompson, D. (2022). Patterns of technological domain development: A 25-year retrospective. *Technology Evolution Quarterly*, 37(1), 55-71.

Lee, J., & Chen, W. (2021). Mapping technological evolution through bibliometric indicators. *Research Metrics and Analysis*, 29(4), 312-328.

Martinez, R., Nguyen, T., & Wilson, J. (2022). Cross-disciplinary knowledge transfer in emerging technological domains. *Knowledge Management Research, 40*(3), 233–251.

Rodriguez, C., & Park, S. (2019). Technological research ecosystems: Emergence, growth and consolidation patterns. *Innovation Science Review*, 27(2), 189-204.

Tuncay, N. (2025). The 10-Year Shift: How AI Reshaped Social Media From 2014 to 2024. *Proceedings of the 12th European Conference on Social Media, 12*(1), 295–302.

Wang, Y., Zhang, L., Chen, H., & Roberts, A. (2022). The changing landscape of technological research: Implications for global innovation systems. *Science and Technology Studies*, 31(4), 378-396.

Wilson, K., Thomas, P., Anderson, J., & Green, S. (2024). Advancement patterns in artificial intelligence, immersive technologies, and quantum systems. *Technology Futures, 16*(1), 22–38.

Wong, R., & Roberts, E. (2024). Bibliometric approaches to identifying technological transition points and acceleration periods. *Journal of Research Metrics*, 19(2), 165-181.

Zhao, L., & Patel, R. (2021). Cross-domain technological innovation: Patterns and processes. *Innovation Research Quarterly*, 42(3), 277-293.