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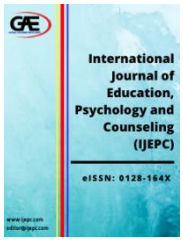

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TRENDS AND DEVELOPMENTS IN INTELLIGENT AGENT FOR SOCIALLY SHARED REGULATED LEARNING (SSRL): A BIBLIOMETRIC REVIEW

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Abstract:

The integration of intelligent agents in supporting Socially Shared Regulation of Learning (SSRL) has gained significant scholarly interest in recent years, aligning with the broader evolution of Artificial Intelligence (AI) in education. Despite its growing relevance, a comprehensive understanding of research trends, influential contributions, and thematic developments within this niche remains limited. This study aims to address that gap by conducting a bibliometric analysis titled "Trends and Developments in Intelligent Agent for Socially Shared Regulated Learning (SSRL)," using a dataset of 1951 publications retrieved from the Scopus database. Employing Scopus Analyzer, OpenRefine, and VOSviewer software, we systematically examined publication output, citation patterns, country contributions, author impact, keyword co-occurrences, and collaboration networks spanning from 1983 to 2025. The analysis revealed a sharp increase in publication volume post-2010, with peak activity occurring between 2010 and 2023, driven predominantly by contributions from the United States, the United Kingdom, China, and Canada. Keyword clustering highlighted dominant themes, including metacognitive support, agent-based learning systems, collaborative regulation, and AI-driven feedback mechanisms. Furthermore, the co-authorship and institutional analysis demonstrated an emerging but fragmented research community,

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suggesting opportunities for enhanced international collaboration. The findings map the intellectual landscape of intelligent agents in SSRL and provide actionable insights for future research. It highlights areas with high potential for interdisciplinary integration and technological innovation. This study provides a foundational perspective for researchers, policymakers, and developers seeking to leverage intelligent agents in fostering effective collaborative learning environments.

Keywords:

Intelligent Agent, Socially Shared Regulation Learning (SSRL), Collaborative Learning

Introduction

Recent developments have become a trending topic in intelligent agent prompts for Socially Shared Regulation of Learning (SSRL), highlighting the integration of Artificial Intelligence (AI) to enhance collaborative learning processes. Furthermore, the significant advancement is the design of Metacognitive Artificial Intelligence (MAI), which is to detect and prompt SSRL by raising group-level metacognitive awareness. However, they faced challenges in effectively facilitating SSRL due to mixed perceptions of reliability and role clarity. This has led to revised prompts and refined design requirements for future iterations, emphasizing the importance of multidisciplinary knowledge in creating adaptive support systems for group metacognitive processes (Järvelä, Nguyen, and Hadwin 2023). Additionally, the use of intelligent tutoring systems, such as Meta Tutor, has demonstrated that learners benefit from collaborative interactions with Pedagogical Agents (PAs) when provided with immediate, directional feedback, resulting in higher learning gains (Harley et al. 2018).

The intersection of human and AI collaboration in SSRL research presents promising opportunities for advancing learning regulation. The introduction of hybrid human-AI shared regulation models, such as the HASRL model, demonstrates how AI can synergistically work with humans to improve learning regulation. This approach leverages AI's strengths to provide real-time, adaptive support, thereby enhancing the effectiveness of SSRL in teaching and learning environments (Järvelä et al. 2023). Empirical research utilizing AI-enhanced Learning Analytics (LA) has revealed distinct deliberation patterns in group interactions, offering new insights into group dynamics and regulatory strategies. These findings underscore the potential of AI to address the complexities of coordinating and synchronizing individual contributions within a group context (Sobocinski et al. 2020).

Moreover, the role of AI in supporting SSRL expands across various cognitive, metacognitive, and motivational areas throughout different phases of learning. Additionally, students perceive AI as an active learning agent capable of assuming roles traditionally held by human educators. Thus facilitating SSRL in Online Collaborative Learning (OCL) environments. Key pedagogical elements necessary for AI to effectively support SSRL include technological, pedagogical, and content knowledge components. These insights provide a foundation for designing educational AI systems that align with theoretical and practical aspects of SSRL, ultimately enhancing collaborative learning outcomes (Kim et al. 2025). The conceptual relationships among these key developments are illustrated in Figure 1.

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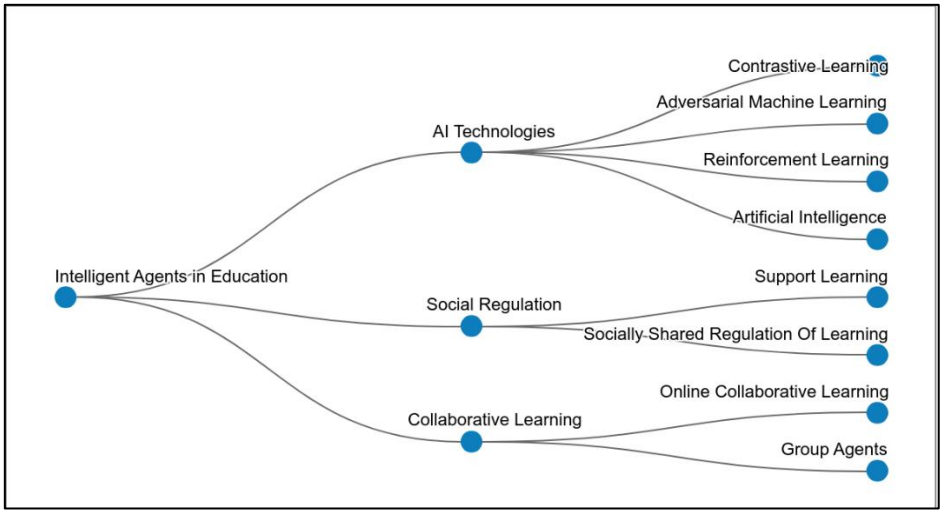

Figure 1: Studies Concept Map.

Research Question

RQ1: What are the research trends observed in studies by year of publication?
RQ2: Which are the ten most highly cited articles?
RQ3: Which country's publications are cited the most?
RQ4: How is co-authorship distributed among countries in terms of collaboration?

Methodology

Bibliometrics encompasses the collection, organization, and analysis of bibliographic data originating from scientific publications (Alves, Borges, and De Nadae 2021; Assyakur and Rosa 2022; Verbeek et al. 2002). Beyond basic statistics, such as identifying publishing journals, publication years, and leading authors , bibliometrics encompasses more sophisticated techniques, including document co-citation analysis. Conducting a successful literature review requires a careful and iterative process to select suitable keywords, search the literature, and perform an in-depth analysis. This approach facilitates the compilation of a comprehensive bibliography and yields reliable results (Fahimnia, Sarkis, and Davarzani 2015). Bearing these considerations in mind, the study strategically homed in on high-impact publications, recognizing them as powerhouses of meaningful insights into the theoretical frameworks that intricately shape the evolving landscape of the research field. In pursuit of unwavering data accuracy, Scopus, renowned for its reliability and comprehensive coverage, was meticulously chosen as the cornerstone for data collection. (Al-Khoury et al. 2022; Khiste and Paithankar 2017; di Stefano, Peteraf, and Veronay 2010). Furthermore, to maintain quality, the study only considered articles published in peer-reviewed academic journals, deliberately excluding books and lecture notes (Sobocinski et al. 2020).

Data Search Strategy

The investigation used a structured screening procedure to devise the search strategy for retrieving articles. Initially, a query string was formulated to concentrate on the terms 'socially shared regulated learning' OR 'intelligent agent,' as defined in Table 1. This preliminary search in Scopus generated 2,755 results. Subsequently, the results were refined by applying inclusion and exclusion criteria related to language and subject area, as summarised in Table 2. Specifically, only articles published in English and categorically within the Computer Science

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subject area were retained. Following the application of these filters, the resultant data set consisted of 1,951 articles, which were subsequently used for bibliometric analysis.

Table 1: The Search String.

Scopus	("intelligent agent" OR "agent-based" OR "autonomous agent" OR "software agent") AND ("social learning" OR "collaborative learning" OR "peer learning" OR "group learning") AND ("regulated learning" OR "self-regulated" OR "structured learning" OR "guided learning") AND ("technology" OR "tool" OR "platform" OR "system") AND ("interaction" OR "engagement" OR "participation" OR "communication").

Table 2: The Selection Criterion in Searching.

Criterion	Inclusion	Exclusion
Language	English	Non-English
Subject Area	Computer Science	Besides Computer Science

Data Analysis

VOSviewer is a user-friendly bibliometric software developed by Nees Jan van Eck and Ludo Waltman at Leiden University, The Netherlands (Van Eck, Nees Jan, & Ludo Waltman. 2007). Its adaptability facilitates the examination of co-authorship, co-citation, and keyword co-occurrence networks, affording researchers a comprehensive insight into research landscapes. The interactive interface, in conjunction with ongoing updates, ensures efficient and dynamic navigation of extensive datasets. The capability of VOSviewer to compute metrics and customize visualizations. Its compatibility with various bibliometric data sources renders it an invaluable resource for scholars who seek to obtain insights into intricate research domains.

One of the standout features of VOSviewer is its capacity to transform intricate bibliometric datasets into visually interpretable maps and charts. With a focus on network visualization, the software excels in clustering related items, analyzing keyword co-occurrence patterns, and generating density maps. Researchers benefit from its user-friendly interface, enabling both novice and experienced users to explore research landscapes efficiently. VOSviewer's continuous development ensures it remains at the forefront of bibliometric analysis, offering valuable insights through metric computation and customizable visualizations. Its adaptability to different types of bibliometric data, such as co-authorship and citation networks, positions VOSviewer as a versatile and indispensable tool for scholars seeking deeper understanding and meaningful insights within their research domains.

Datasets comprising information on the publication year, title, author name, journal, citation, and keywords in PlainText format were procured from the Scopus database, spanning the period from 2004 to December 2024. These datasets were then analyzed using VOSviewer software version 1.6.19. Through the application of VOS clustering and mapping techniques, this software facilitated the examination and generation of maps. Offering an alternative to the Multidimensional Scaling (MDS) approach, VOSViewer focuses on situating items within low-dimensional spaces, ensuring that the proximity between any two items accurately reflects

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their relatedness and similarity (van Eck and Waltman 2010). In this respect, VOSViewer shares a similarity with the MDS approach (Appio, Cesaroni, and Di Minin 2014). Diverging from MDS, which primarily engages in the computation of similarity metrics like cosine and Jaccard indices, VOS utilizes a more fitting method for normalizing co-occurrence frequencies such as the Association Strength (AS_{ij}), and it is calculated as Van Eck and Waltman (2007):

$$AS_{ij} = \frac{C_{ij}}{w_i w_j},$$

which is "proportional to the ratio between, on the one hand, the observed number of co-occurrences of i and j, and on the other hand, the expected number of co-occurrences of i and j under the assumption that co-occurrences of i and j are statistically independent" (Van Eck and Waltman 2007).

Findings

RQ1: What Are The Research Trends Observed In Studies By Year Of Publication?

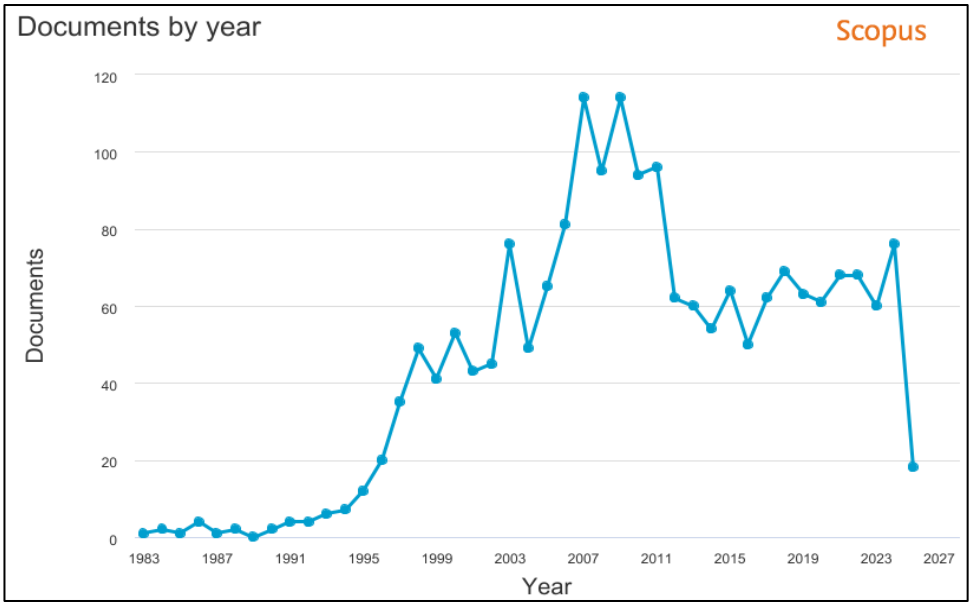

Figure 2: Research Trends To The Year Of Publication.

Table 3: Year and Total of publication.

Year	Total Publication	Percentage	Year	Total Publication	Percentage
2025	18	0.94	2004	49	2.51
2024	76	3.9	2003	76	3.9
2023	60	3.08	2002	45	2.31
2022	68	3.49	2001	43	2.2
2021	68	3.49	2000	53	2.72
2020	61	3.13	1999	41	2.1
2019	63	3.23	1998	49	2.51

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2018	69	3.54	1997	35	1.79
2017	62	3.18	1996	20	1.03
2016	50	2.56	1995	12	0.62
2015	64	3.28	1994	7	0.36
2014	54	2.77	1993	6	0.31
2013	60	3.08	1992	4	0.21
2012	62	3.18	1991	4	0.21
2011	96	4.92	1990	2	0.1
2010	94	4.82	1988	2	0.1
2009	114	5.84	1987	1	0.05
2008	95	4.87	1986	4	0.21
2007	114	5.84	1985	1	0.05
2006	81	4.15	1984	2	0.1
2005	65	3.33	1983	1	0.05

The bibliometric data indicates a marked increase in publication activity concerning the research topic over time, particularly commencing in the early 2000s. The years 2007 and 2009 emerged as the most productive, each recording 114 publications, which constituted 5.84% of the total research output—highlighting peak academic interest during this period. The years 2008 (95 publications, 4.87%), 2010 (94, 4.82%), and 2011 (96, 4.92%) closely followed, signifying a sustained escalation in scholarly focus on the field across successive years. This trend suggests a phase of maturation and expansion within the research area, presumably facilitated by technological advancements and increasing academic interest in AI-supported learning environments and SSRL. Conversely, in the initial decades—specifically the 1980s and early 1990s—research output was minimal. Years such as 1983, 1985, and 1987 each recorded only one publication, comprising merely 0.05% of the total output. This paucity of publications implies that the central concepts of the study, including intelligent agents and SSRL, had not yet achieved significant prominence within academic discourse. A gradual increase in publications commenced in the mid-1990s, establishing the groundwork for the exponential growth observed in subsequent decades. Between 2012 and 2025, the number of publications remained relatively stable, with annual outputs ranging from 50 to 76 articles, reflecting sustained scholarly engagement. The most recent years—2023 to 2025—perpetuate this trend, emphasizing ongoing research interest and relevance. The consistent distribution over the past decade, coupled with the early peak observed between 2007 and 2011, indicates a well-established and active research community. This temporal pattern highlights both the historical development of the field and its contemporary relevance in addressing educational challenges through intelligent systems and collaborative learning innovations.

RQ2: Which Are The Ten Most Highly Cited Articles?

The citation analysis of top authors and works related to intelligent agents reveals foundational and highly influential contributions to the field. The most cited work is by Wooldridge and Jennings (1995), *"Intelligent Agents: Theory and Practice,"* with 4,654 citations, clearly establishing it as a seminal paper that laid the groundwork for understanding agent theory and practical applications. Another early and impactful contribution comes from Tambe et al. (1995), whose work on intelligent agents in simulation environments garnered 199 citations, highlighting early efforts in applying agent-based technologies to interactive systems.

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Collectively, these earlier works significantly shaped the foundational theory and application of intelligent agents in AI and computer science.

More recent research demonstrates a diversification of intelligent agent applications across interdisciplinary domains. For instance, Anderson & Anderson (2007) explored machine ethics, garnering 314 citations, which signals a growing concern about the ethical dimensions of autonomous agents. Similarly, Chumachenko et al. (2019) introduced an agent-based model in epidemiology, achieving 344 citations, showcasing the expanding role of intelligent agents beyond education and computing in the health and social sciences. Studies like Kulesza et al. (2012), which investigated user mental models and personalization in agents, emphasized the rising interest in human-agent interaction and usability, reflecting a shift from theory to more user-centric implementations.

The inclusion of contemporary works such as Moussawi et al. (2021), which examined perceptions of intelligence and anthropomorphism in agent adoption, with 218 citations, underscores the field's continuing relevance and evolution. This suggests that modern research is not only concerned with agent capabilities but also with how users interact with, trust, and accept these systems. The breadth of publication venues, ranging from AI Magazine to Electronic Markets, also indicates the wide-ranging impact of intelligent agent research across both technical and socio-technical domains. Together, the table reflects a maturing research landscape that bridges theory, design, ethics, and real-world implementation of intelligent agents.

Table 4: Top Ten Most Cited Articles.

Authors	Title	Year	Source Title	Cited by
Wooldridge M.; Jennings N.R [18]	Intelligent agents: Theory and practice	1995	The Knowledge Engineering Review	4654
Kulesza T.; Stumpf S.; Burnett M.; Kwan I. [19]	Tell me more? the effects of mental model soundness on personalizing an intelligent agent	2012	Conference on Human Factors in Computing Systems - Proceedings	195

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Shen W. [20]	Distributed Manufacturing Scheduling Using Intelligent Agents	2002	IEEE Intelligent Systems	235
Chen H.; Finin T.; Joshi A.; Kagal L.; Perich F.; Chakraborty D [21]	Intelligent agents meet the semantic web in smart spaces	2004	IEEE Internet Computing	205
Anderson M.; Anderson S.L[22]	Machine ethics: Creating an ethical intelligent agent	2007	AI Magazine	314
Chumachenko D.; Meniailov I.; Bazilevych K.; Kuznetsova Y.; Chumachenko T. [23]	Development of an intelligent agent-based model of the epidemic process of syphilis	2019	International Scientific and Technical Conference on Computer Sciences and Information Technologies	344
Tambe Milind; Johnson W.Lewis; Jones Randolph M.; Koss Frank; Laird John E.; Rosenbloom Paul S.; Schwamb Karl[24]	Intelligent agents for interactive simulation environments	1995	AI Magazine	199
Maulsby David; Greenberg Saul; Mander Richard [25]	Prototyping an intelligent agent through Wizard of Oz	1993	Conference on Human Factors in Computing Systems - Proceedings	222
Moussawi S.; Koufaris M.; Benbunan-Fich R. [26]	How perceptions of intelligence and anthropomorphism affect the adoption of personal intelligent agents	2021	Electronic Markets	218

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RQ3: Which Country's Publications Are Cited The Most?

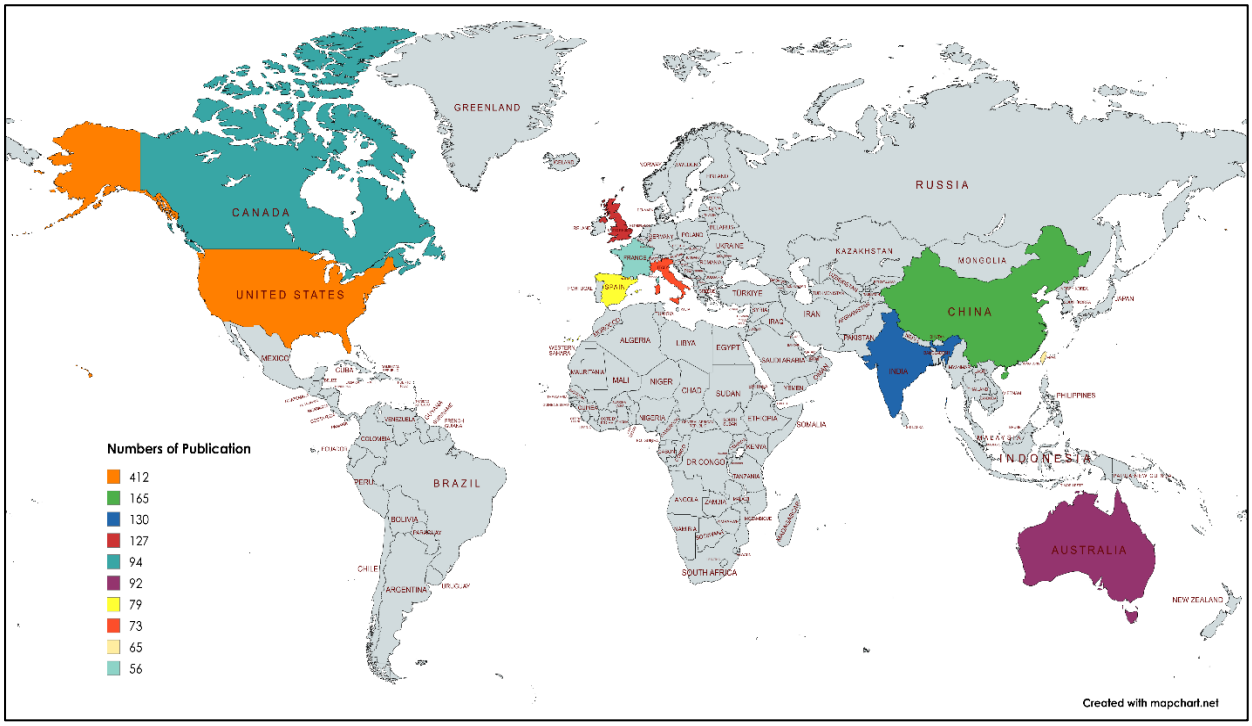

Figure 3: Country With Most Publications Cited.

The distribution of publications by country, as shown in Figure 3, highlights the global landscape of research on intelligent agents. The United States leads with a commanding total of 412 publications, indicating its dominant role in advancing research and development in this area. This is likely driven by a strong ecosystem of universities, research institutions, and technology companies that prioritize innovation in AI and educational technologies. China (165 publications) and India (130) follow as significant contributors from Asia, reflecting the rapid growth in digital learning and smart technology initiatives within these nations. The United Kingdom, with 127 publications, rounds out the top four, showcasing its consistent investment in AI research and higher education.

The next tier of contributors includes Canada (94) and Australia (92), both of which maintain active research communities with a strong emphasis on intelligent systems and collaborative learning environments. Meanwhile, European countries such as Spain (79), Italy (73), and France (56) show steady participation in the field, while Taiwan (65) stands out as a key contributor from East Asia. These figures also illustrate the wide-reaching interest and involvement across regions, underscoring intelligent agents as a globally relevant research domain.

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RQ4: How Is Co-Authorship Distributed Among Countries In Terms Of Collaboration?

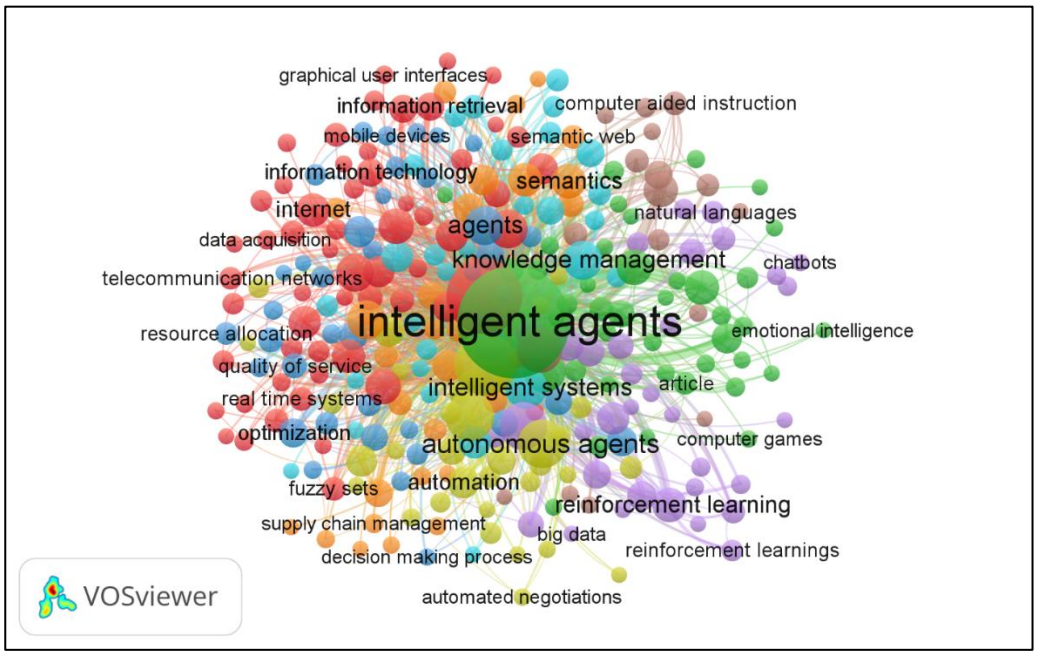

Figure 4: Network Visualization Map of Keywords' Co-Occurrence.

The keyword analysis from VOSviewer reveals a strong concentration around the term "agent-based," with the highest number of occurrences (50) and a total link strength of 282. This indicates its central role and strong co-occurrence with other terms in the dataset, underlining its prominence in research themes involving simulation, modeling, and complex system representation. Closely following is the keyword "agent" (40 occurrences, 237 link strength), which serves as a foundational term connecting various subfields in intelligent systems. These high values suggest that the concept of agents—software entities capable of autonomous actions—is a dominant theme, likely reflecting its widespread application in AI, robotics, and distributed computing environments.

Other related keywords such as "agent architectures," "agent behavior," and "agent model" demonstrate a focused scholarly interest in the structural and functional design of agents. These terms point to deeper investigations into how agents are designed to function individually and collaboratively, emphasizing aspects such as behavior modeling, decision-making frameworks, and architectural configurations. Meanwhile, "agent-based simulation" underscores the practical application of these models in simulating real-world systems, validating theoretical constructs through computational experimentation, particularly in areas like social science, logistics, and system dynamics.

In addition, the appearance of emerging terms such as "adversarial machine learning" and "affective computing" suggests the expansion of agent-related research into newer, interdisciplinary areas. "Adversarial machine learning" indicates a concern for robustness and security in agent design, especially in learning environments that are vulnerable to manipulation. "Affective computing," on the other hand, reflects an interest in developing emotionally aware agents that can interpret and respond to human affective states, contributing to more naturalistic human-computer interaction. These keywords, although less frequent, highlight innovative directions that complement and challenge traditional agent-based systems.

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RQ5: What Is The Co-Authorship By Countries Collaboration?

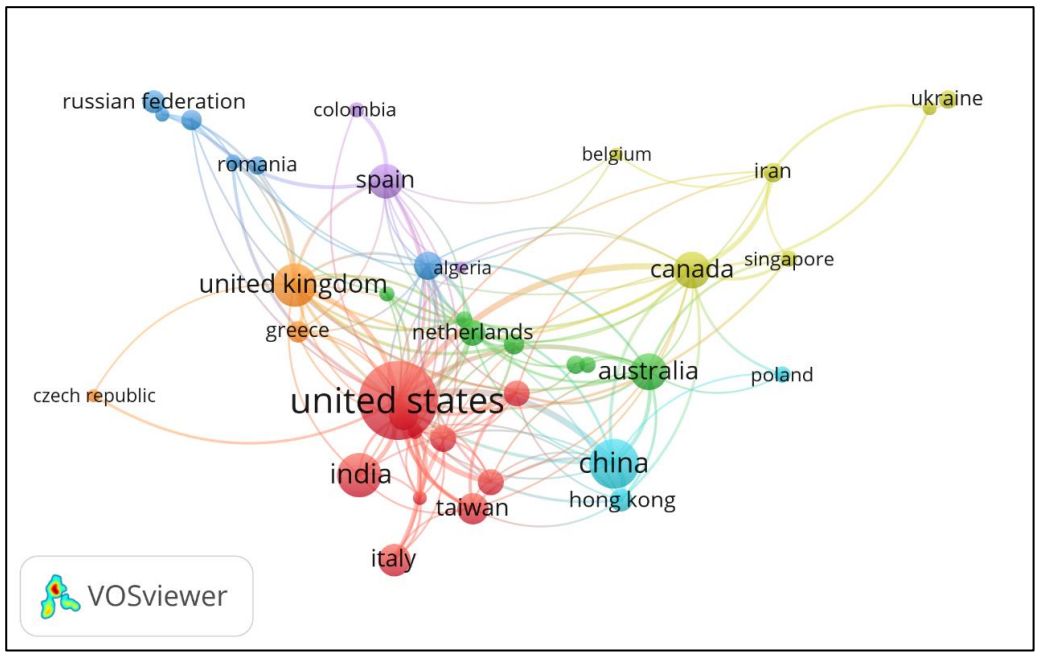

Figure 5: Network Visualization Map of Co-Authorship by Countries Collaboration.

The bibliometric data in the table illustrates a detailed global distribution of research productivity, influence, and connectivity in the field of intelligent agents and related studies. The United States leads with a commanding total of 410 documents, 5,870 citations, and the highest total link strength of 102, underscoring not only its prolific output but also its central role in global research networks. Similarly, the United Kingdom stands out with 127 documents and an impressive 6,387 citations, reflecting a high impact per publication and substantial scholarly influence. Other top contributors in both productivity and influence include Canada (93 documents, 1,351 citations), China (165 documents, 976 citations), and Australia (92 documents, 1,204 citations), highlighting active participation from North America, Europe, and the Asia-Pacific region.

Several countries show strong citation performance relative to their publication count, indicating high-quality or widely referenced work. For example, Hong Kong (35 documents, 783 citations) and Taiwan (64 documents, 807 citations) both demonstrate significant citation impact, suggesting their research outputs are highly valued in the field. India, while producing a high volume of publications (130 documents), shows a relatively moderate citation count (1,042), which may indicate either newer contributions or lower citation visibility. France (471 citations) and Germany (455 citations) also reflect solid impact within Europe, alongside consistent connectivity, as shown by their link strength values (20 and 24, respectively).

Several emerging and developing countries, such as Brazil (46 documents, 152 citations), Egypt (16 documents, 153 citations), and Indonesia (18 documents, 66 citations) illustrate a growing engagement with the field. However, their total link strength remains modest. This suggests limited integration into larger global research networks, pointing to potential opportunities for increased collaboration and enhanced visibility. Countries like Switzerland, South Korea, and the Netherlands also stand out with higher citation counts and moderate link

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strengths, suggesting solid contributions with opportunities to further deepen international ties. Overall, the table reflects a diverse and interconnected research landscape, with clear leaders and rising contributors shaping the development of intelligent agent technologies worldwide.

Conclusion

This investigation sought to examine trends and developments within the domain of intelligent agents for SSRL from a bibliometric perspective. Using data sourced from Scopus and analyzed through OpenRefine and VOSviewer, this study addressed fundamental research questions concerning publication trends, influential works, national contributions, keyword patterns, and international collaborations. The primary objective was to chart the intellectual landscape and to elucidate the structure, dynamics, and impact of research on intelligent agents in SSRL contexts. The analysis identified a pronounced escalation in scholarly interest beginning in the early 2000s, with a peak in publication activity observed between 2007 and 2011 and sustained output anticipated through 2025. The key findings identified the United States, the United Kingdom, China, and Canada as the predominant contributors, both in terms of publication volume and impact of citations. Highly cited articles concentrated on foundational theories, ethical considerations, agent-based modeling, and user interaction design, whereas keyword analysis emphasized dominant research themes, including agent-based systems, metacognitive support, and AI-driven collaboration. The network visualizations uncovered emerging interdisciplinary topics, including affective computing and adversarial machine learning, indicating an expansion in the research scope. This study provides a comprehensive overview of the evolution and current state of intelligent agent research within SSRL, providing valuable information for researchers, educators, and developers interested in advancing collaborative learning technologies. Although the analysis affords robust insights, limitations encompass the sole reliance on the Scopus database and the exclusion of non-English and non-journal publications, potentially omitting pertinent contributions. Future research could be extended to include multiple databases and more in-depth qualitative analyses to further enrich comprehension. The findings underscore the utility of bibliometric methods in unveiling critical developments and guiding future inquiries in this dynamic field of study.

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