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MAPPING RESEARCH TRENDS IN AGENT-DRIVEN SOCIALLY SHARED REGULATION LEARNING (SSRL) FOR DIGITAL LEARNING PLATFORM: A BIBLIOMETRIC PERSPECTIVE (2018-2024)

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Abstract:

The recent surge in artificial intelligence (AI) research has transformed applications across various sectors, including healthcare, education, manufacturing, and digital learning. Although digital learning, collaborative learning, and socially shared regulation learning (SSRL) have experienced significant growth, a thorough examination of scholarly contributions, emerging trends, and influential figures in these fields is still absent. Despite increasing interest in utilizing intelligent agents to enhance SSRL, there is a lack of comprehensive mapping in this interdisciplinary area. Addressing this gap, this study systematically analyses 1,200 publications indexed in Scopus, covering a period from 2018 to 2024. Using Scopus analyzer and VOSviewer, we examined publication trends, co-authorship networks, key research clusters, and thematic patterns. The keywords guiding this analysis were "agent," "digital learning," "socially shared regulation learning," and "collaborative learning." Findings reveal significant growth in this research area, with prominent clusters focused on intelligent agent implementation, collaborative learning frameworks, and SSRL in educational settings. Key contributors and leading journals were identified, highlighting the most influential entities driving research in this field. In conclusion, the study underscores a progressive shift towards integrating intelligent agents in SSRL, suggesting impactful directions for future research and the potential for intelligent agent applications to enhance collaborative digital learning environments. This trend mapping offers valuable insights into both current advancements and prospective developments in agent-driven SSRL.

Keywords:

Agent, Socially Shared Regulation Learning (SSRL), Digital Learning, Collaborative Learning.

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Introduction

The rapid integration of intelligent technologies in education has transformed digital learning environments, making them more interactive, collaborative, and personalized. Socially Shared Regulation of Learning (SSRL) is a framework that emphasizes learners' joint efforts in regulating cognitive, metacognitive, and socio-emotional processes to achieve shared learning objectives. Researchers like Hadwin, Järvelä, and Miller (2021) highlight SSRL's role in enhancing collaboration by enabling students to actively regulate not only their learning but also group dynamics and goal-setting processes. With the incorporation of intelligent agents into SSRL practices, there is growing potential to improve these collaborative learning experiences through real-time, adaptive support. Intelligent agents function as digital facilitators, designed to assist learners in monitoring progress, encouraging participation, and offering feedback. Dillenbourg *et al.* (2020) underscore that intelligent agents can guide interactions by structuring group tasks and providing timely prompts, which is crucial in maintaining engagement and alignment with SSRL principles.

The application of intelligent agents is rooted in theories of collaborative and self-regulated learning. Winne and Hadwin (2013), foundational theorists in this area, emphasize the importance of strategic monitoring and feedback in regulated learning, which intelligent agents now make feasible in digital platforms. Roschelle and Teasley (1995) initially highlighted shared regulation's necessity in ensuring effective collaboration, a role those intelligent agents fulfill through features like personalized task distribution and progress tracking. Recent advances by Kirschner, Sweller, and Clark (2006) advocate for intelligent systems that actively facilitate group decision-making, reduce cognitive load, and support sustained engagement, further affirming the value of agent-driven SSRL.

Zheng, Yang, and Rosé (2022) have employed advanced network analysis to examine research trends on agent-driven SSRL, revealing an increased focus on its applications within digital learning platforms. Noroozi, Kirschner, and Biemans (2022) found that intelligent agents are effective in managing group dynamics, ensuring equitable participation, and supporting learners through complex collaborative tasks. Järvelä, Volet, and Hadwin (2022) further discuss the socio-emotional benefits of agent-driven SSRL, noting that these agents provide critical support for conflict resolution, motivation, and self-assessment, all key to group success.

As digital education evolves, agent-driven SSRL shows promise for meeting new educational demands, offering tailored, efficient learning support across diverse contexts. Through the alignment of SSRL principles with AI-based tools, future research is set to advance the understanding of collaborative regulation, exploring its implications for enhanced, learner-centred digital education.

Literature Review

Recent advancements in digital education have increasingly focused on integrating intelligent agents to enhance Socially Shared Regulation of Learning (SSRL), fostering collaborative regulation processes within learning platforms. SSRL, a framework wherein learners co-regulate cognitive, metacognitive, and emotional processes to achieve shared goals, has become essential in digital environments. Järvelä and Hadwin (2013) emphasize SSRL's importance in promoting shared goal setting, monitoring, and adjustment among learners, highlighting its relevance in complex, collaborative online spaces. Intelligent agents, as

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underscored by Dillenbourg *et al.* (2020), have been incorporated into digital learning to enhance SSRL by providing structured guidance, feedback, and facilitation, adapting their responses based on real-time analysis of learners' interactions.

Research has shown that intelligent agents support SSRL by actively monitoring and adjusting instructional support to foster optimal group dynamics and learning outcomes. Kirschner, Sweller, and Clark (2006) explore using agent-driven guidance to manage cognitive load, distribute roles equitably, and enhance collaborative engagement. Hadwin and Winne (2022) further discuss that these agents facilitate co-regulation by prompting learners to engage in reflection, self-assessment, and peer feedback, which align with SSRL practices. Zheng *et al.* (2022) highlight the agents' role in fostering a supportive learning environment where participation is balanced and socio-emotional challenges are addressed, which is critical for sustained group performance.

Network analysis studies by Noroozi, Biemans, and Mulder (2021) provide insights into how intelligent agents in SSRL contribute to more meaningful interactions by adapting prompts to the group's needs and creating a responsive and adaptive learning atmosphere. Roschelle and Teasley (1995) previously identified shared regulation as critical in digital collaborative environments, noting that agent-driven SSRL mechanisms enable the co-construction of knowledge, which is essential for successful digital collaboration. Fischer and Kollar (2022) further emphasize the potential of agents to act as mediators in collaborative problem-solving, guiding learners through complex tasks and promoting effective communication.

Zheng, Yang, and Rosé (2022) also analyze recent trends, suggesting that agent-driven SSRL is becoming integral to digital platforms due to its ability to enhance both individual and group performance. Järvelä, Volet, and Hadwin (2022) argue that as agents support socio-emotional and motivational aspects, they play an essential role in fostering a cohesive learning environment. These findings suggest that the integration of intelligent agents in SSRL frameworks is not only enhancing collaborative interactions but is also paving the way for adaptive, personalized learning support across varied educational settings.

Research Questions

RQ1: What are the research trends for the topic to the year of the publication?
RQ2: Who writes the most cited articles?
RQ3: What are the types of documents by subject of research?
RQ4: What are the popular keywords related to the study?
RQ5: What are the top 10 countries by citation number?

Methodology

Bibliometrics involves gathering, organizing, and analyzing information from scientific publications to gain insights into research trends (Alves *et al.*, 2021; Assyakur & Rosa, 2022; Verbeek *et al.*, 2002). This approach includes basic metrics like popular journals, publication years, and key authors, as well as more complex methods such as document co-citation analysis, which examines how often documents are cited together (Wu & Wu, 2017). Conducting a thorough literature review is an iterative process: it requires identifying relevant keywords, performing comprehensive searches, and analyzing the findings to create a complete bibliography with reliable results (Fahimnia *et al.*, 2015). In this study, we focused on top-quality publications for their insights into key theories shaping the field. To ensure accuracy,

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we used the SCOPUS database for data collection (Al-Khoury *et al.,* 2022; di Stefano *et al.,* 2010; Khiste & Paithankar, 2017), selecting only articles published in peer-reviewed academic journals, while excluding books and lecture notes (Gu *et al.,* 2019). The Scopus database, known for its broad coverage, provided us with publications from 2018 to December 2024 for our analysis.

Data Search Strategy

The study employed a screening sequence to determine the search terms for article retrieval. The study was initiated by querying the Scopus database with online TITLE ((SSRL OR "Agent") AND ("DIGITAL LEARNING" OR "COLLABORATIVE LEARNING"), thereby assembling 3767 articles. The final search string TITLE ((ssrl OR agent) AND ('digital AND learning' OR 'collaborative AND learning')) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2023) OR LIMIT-TO (PUBYEAR, 2024)), refinement included 1200 articles which was used for bibliometric analysis. As of December 2024, all articles from the Scopus database relating to the title were incorporated into the study.

Data Analysis

VOSviewer, developed by Nees Jan van Eck and Ludo Waltman at Leiden University, Netherlands (van Eck & Waltman, 2010, 2017), is a widely used bibliometric software valued for its ease of use in visualizing and analyzing scientific literature. Designed to create clear network visualizations, it specializes in clustering related elements and producing density maps. The tool's adaptability supports the analysis of co-authorship, co-citation, and keyword co-occurrence networks, offering comprehensive insights into research landscapes. Its intuitive interface and continuous updates make it efficient for handling large datasets dynamically. VOSviewer's capacity to calculate metrics, customize visualizations, and integrate with various bibliometric data sources has solidified its importance among scholars working with complex research domains.

One key attribute of VOSviewer is its ability to convert complex bibliometric data into easily interpreted maps and charts. With a focus on network visualization, the software stands out for its capacity to cluster related entities, analyze keyword co-occurrence patterns, and generate density maps. Its user-friendly design supports efficient exploration for both beginners and advanced users. The software's ongoing development keeps it at the forefront of bibliometric analysis, providing insightful metrics and customizable visualization options. Due to its adaptability across different types of bibliometric data, such as co-authorship and citation networks, VOSviewer has become an essential resource for scholars aiming to uncover deeper research insights within their fields.

Datasets in PlainText format containing details on publication year, title, author names, journal, citations, and keywords were retrieved from the Scopus database, covering the period from 2020 to December 2023. These datasets were processed using VOSviewer version 1.6.19, which, through clustering and mapping techniques, enabled a detailed examination of the data. As an alternative to the Multidimensional Scaling (MDS) approach, VOSviewer organizes items within a low-dimensional space, positioning them such that the distance between any two

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items represents their level of similarity (van Eck & Waltman, 2010). This approach bears similarities to MDS (Appio *et al.*, 2014), though VOSviewer diverges in its normalization technique. Meanwhile, MDS typically applies similarity metrics like cosine and Jaccard indices, and VOSviewer adopts a normalization method that utilizes association strength (ASij), as shown in Figure 2, providing a refined calculation for co-occurrence frequency (van Eck & Waltman, 2007).

$$AS_{ij} = \frac{C_{ij}}{W_i W_j}$$

Figure 2: Formula for Association Strength.

Result and Finding

RQ1: What Are The Research Trends In Online Learning Studies According To The Year Of Publication?

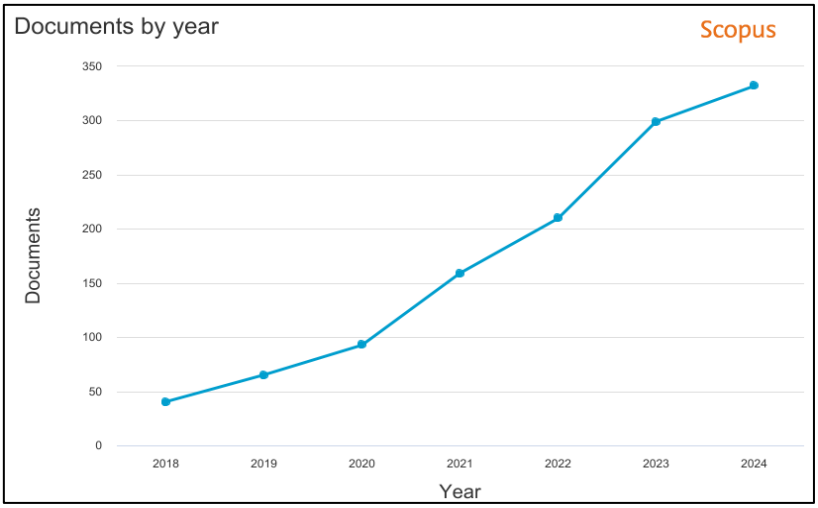

Figure 1: Plotting Document Publication by Years.

Figure 1 is a line graph showing the number of documents published in the journal annually from 2018 to 2023. As you can see, there has been a steady increase in the number of documents published in the journal over five years. Starting from approximately 40 documents in 2018, the field has experienced consistent year-over-year increases, with particularly steep growth observed between 2021 and 2023, where publications more than doubled from around 150 to 300 documents. This accelerated growth pattern suggests a rapidly expanding research interest in the intersection of intelligent agents and self-regulated learning in digital education.

The sharp upward trajectory, reaching approximately 330 documents by 2024, indicates the field's growing maturity and increasing recognition within the academic community. Several factors likely contribute to this trend, including the global shift toward digital learning during the COVID-19 pandemic (as evidenced by the steeper increase post-2020), advancing artificial

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intelligence technologies, and greater emphasis on personalized learning experiences. The consistent growth pattern also suggests sustained funding, research interest, and practical applications in educational technology, positioning agent-driven SSRL as an increasingly significant study area in educational research and development.

It is also possible that both of these factors are playing a role in the increase in the number of documents published in the journal. It is likely that the journal's increasing popularity is attracting more submissions from researchers and that the growing amount of research being conducted in the field is also leading to more submissions. Whatever the reason for the increase, it is clear that the journal is becoming more and more popular with researchers. This is a positive sign for the journal, and it suggests that it is playing an important role in the field.

RQ2: Who Writes The Most Cited Articles?

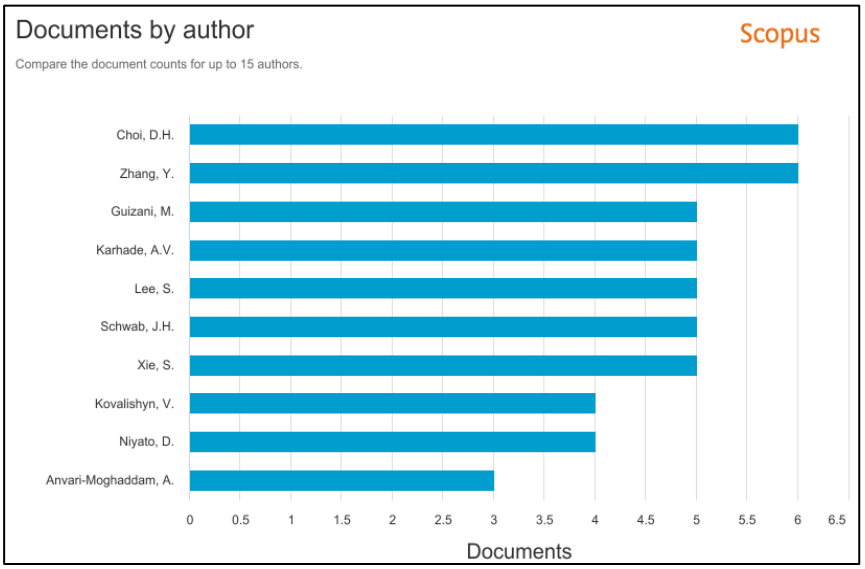

Figure 2: Documents Publication by Author.

Table 1 Document's Percentage of Publication by Ten Top Authors.

Author's Name	Number of Document	Percentages (%)
Choi, D.H.	6	16.22
Zhang, Y.	6	16.22
Guizani, M.	5	13.51
Karhade, A.V.	5	13.51
Lee, S.	5	13.51
Schwab, J.H.	5	13.51
Xie, S.	5	13.51
Kovalishyn, V.	4	10.81
Niyato, D.	4	10.81
Anvari-Moghaddam, A.	3	8.11

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The Scopus data highlights that Choi, D.H. and Zhang, Y. are the leading researchers in agent-driven Self-Regulated Learning (SRL) for digital learning platforms, each having published around six documents. They are followed by a group of five researchers—Gulzani, M., Karnade, A.V., Lee, S., Schwab, J.H., and Xie, S.—who have each contributed approximately five publications, forming a strong core of contributors in this field. A secondary tier of researchers, including Kovalishyn, V. and Niyato, D., has published about four documents each, indicating an active yet more specialized role in advancing the topic.

Anvari-Moghaddam, A. appears to play a supporting or emerging role with three publications. Overall, the relatively narrow range of publication counts (3–6 documents) suggests a concentrated and specialized research community. The data reflects a collaborative and interconnected field where a small group of researchers is pushing the development of agent-driven SRL in digital learning platforms. The similar publication counts among many authors, particularly those with five documents, likely point to ongoing collaborations or parallel research efforts within the same technological domain, typical of a developing and niche study area.

RQ3: What Are The Types Of Documents By Subject Of Research?

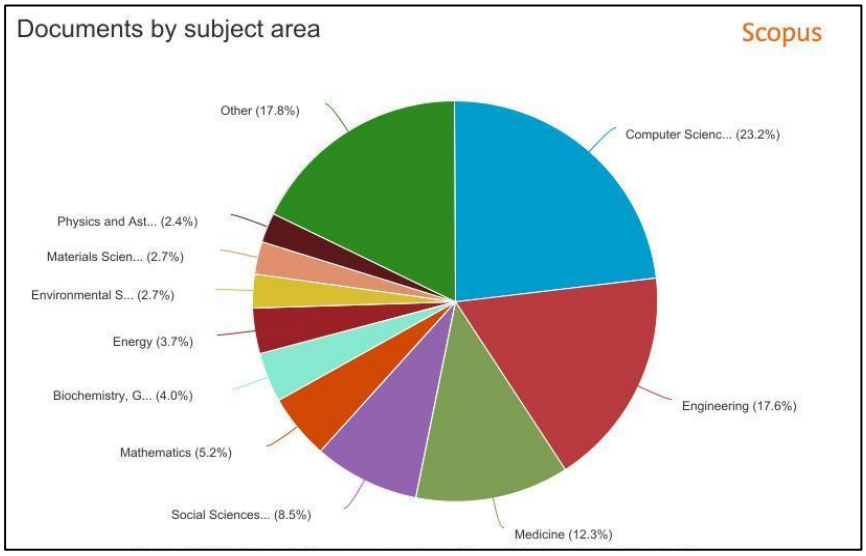

Figure 3: Document Publication by Subject Area.

The pie chart reveals that Computer Science dominates the research landscape with **23.2%** of publications, followed by Engineering (**17.6%**) and Medicine (**12.3%**), collectively accounting for over **53%** of the total documents. This distribution strongly indicates that Agent in Regulated Learning in digital platforms is primarily approached from a technical and implementation perspective, with computer science leading the development of algorithms, frameworks, and computational models. The significant engineering presence suggests a strong focus on system design, architecture, and practical implementation of these learning platforms.

The second tier of contributing fields includes Social Sciences (**8.5%**), Mathematics (**5.2%**), and Biochemistry/Genetics (**4.0%**), which together represent the interdisciplinary nature of SSRL research. The social sciences component likely addresses pedagogical theories, learning behaviors, and educational psychology aspects, while mathematics contributions probably

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focus on modeling learning patterns and developing analytical frameworks. It's noteworthy that Energy (**3.7%**), Environmental Science (**2.7%**), and Materials Science (**2.7%**) have smaller but notable contributions, suggesting applications or methodological adaptations of SSRL in these specific domains.

A significant portion (**17.8%**) falls under "Other" categories, highlighting the broad appeal and versatility of Agent-Driven SSRL research across various disciplines not explicitly categorized. This diverse distribution emphasizes the multidisciplinary nature of digital learning platforms and suggests that SSRL implementation requires expertise from multiple domains to create effective, adaptive, and user-centered learning environments. The relatively high percentage of medicine-related publications (**12.3%**) also indicates substantial applications in medical education and healthcare training, where adaptive learning systems are particularly valuable.

RQ4: What Are The Popular Keywords Related To The Study?

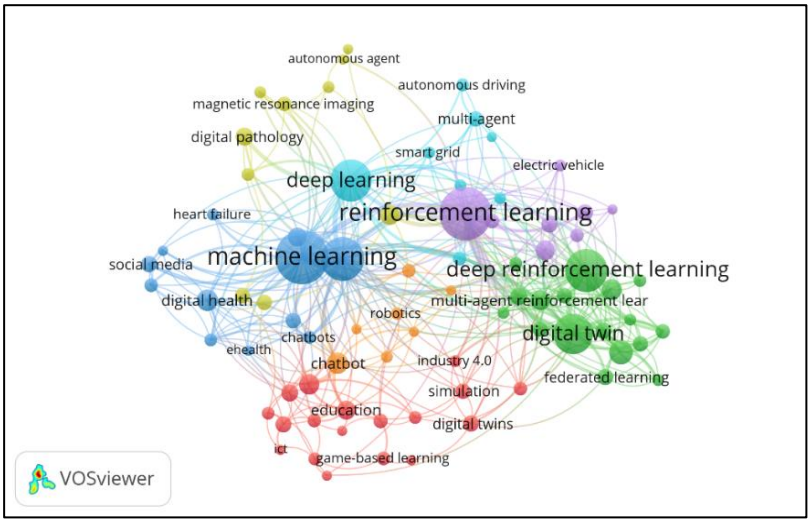

Figure 4: Network Visualization of Research Keywords.

The map shows several clusters of keywords that represent the main themes and topics within the research literature. The analysis of the research trends in agent-driven socially shared regulation of learning (SSRL) for digital learning platforms reveals a significant and growing interest in various technologies that support educational advancements. In particular, artificial intelligence (AI), deep learning, and machine learning have emerged as dominant fields, reflecting their increasing role in enhancing learning platforms.

Among these, deep reinforcement learning and multi-agent systems have shown notable advancements in improving SSRL by offering more adaptive and personalized learning experiences. Keywords like digital transformation, e-learning, and digital competence highlight the shift toward digital environments, indicating a broader trend in utilizing technology to support collaborative learning. Moreover, multi-agent systems and conversational agents stand out as important tools in fostering interaction and engagement, which are essential for successful SSRL processes.

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Furthermore, the growing integration of technologies such as blockchain, cloud computing, and augmented reality within educational platforms suggests a trend toward creating more immersive and secure digital learning ecosystems. These innovations help address the complex needs of modern learners, providing personalized feedback, adaptive learning pathways, and collaborative problem-solving opportunities.

The research also emphasizes the increasing relevance of multi-agent deep reinforcement learning in the educational context, underlining its potential in managing multiple agents in a learning environment to optimize interactions and outcomes. This trend aligns with the broader movement toward creating intelligent, data-driven learning platforms that are capable of supporting diverse learner needs through advanced agent-driven mechanisms.

Overall, the network visualization map provides a valuable overview of the research landscape by highlighting the key themes, areas of focus, and potential areas for further investigation. By analyzing the relationships between keywords, you can gain deeper insights into the trends and nuances within this field of research.

RQ5: What Are The Popular Keywords Related To The Study?

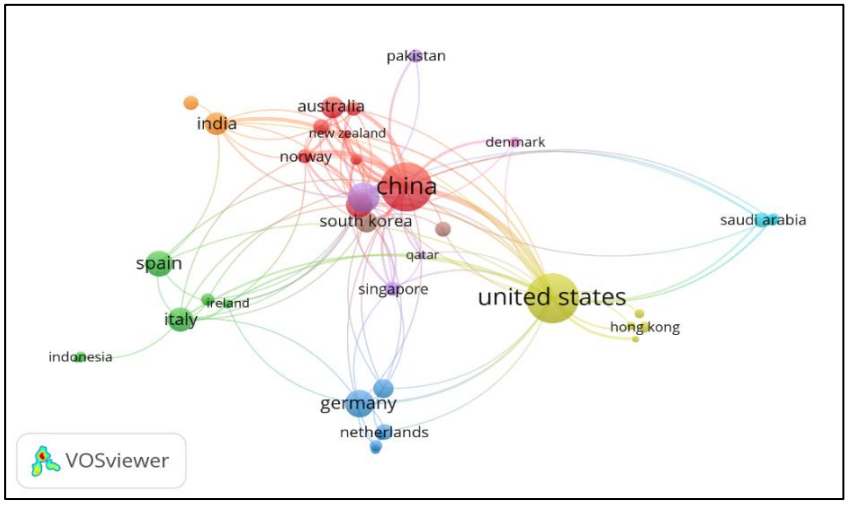

Figure 5: Countries Whose Authors Collaborate the Research Area.

The data analysis from VOSviewer reveals a significant global distribution of research on agent-driven Socially Shared Regulation Learning (SSRL) in digital learning platforms. The United States leads with the highest number of documents and citations, followed by China, the United Kingdom, and Australia. These countries show strong academic output and high citation counts, suggesting they are key contributors to the field. The total link strength metric also highlights a robust network of academic connections, especially in the United States and China, which may reflect a well-established and active research community. Other countries such as Canada, Germany, and the Netherlands also demonstrate notable contributions, with each having substantial citation records and document counts, indicating the widespread interest in this study area across different regions.

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Despite the dominance of a few countries, many others contribute to the field, although to a lesser extent. Countries like Brazil, Chile, and Egypt have fewer publications and citations, pointing to a more localized or emerging interest in SSRL and agent-driven learning systems. The link strength in these countries is relatively low, suggesting less integration or collaboration with the leading research hubs. However, these smaller research communities may still offer valuable perspectives and could benefit from further development and international academic collaboration. This global analysis underscores the importance of diverse contributions to the evolving research landscape of SSRL in digital learning environments.

Discussion and Conclusion

The steady growth in publications related to agent-driven self-regulated learning (SSRL) for digital learning platforms from 2018 to 2024 suggests a field that is rapidly expanding and gaining increasing recognition in academic circles. The surge in publications, especially post-2020, can be attributed to factors such as the global shift towards digital education, the growing role of artificial intelligence, and the increasing focus on personalized learning. These developments reflect a maturing research area, which is attracting more attention, funding, and practical applications, further emphasizing the importance of SSRL in educational technology. By 2024, the upward trajectory of publications indicates that agent-driven SSRL is becoming a significant and well-established field within educational research.

The research landscape shows a concentrated and collaborative community, with key contributors helping to shape the direction of this niche area. Computer science, engineering, and medicine dominate the landscape, highlighting the technical and practical focus of the research. Social sciences and mathematics also play a crucial role, indicating the interdisciplinary nature of SSRL research. The field's broad appeal is evident in the wide range of disciplines contributing to its growth, with applications spanning various domains, including healthcare, energy, and environmental sciences. This diverse involvement underscores the potential of agent-driven SSRL to transform digital learning environments by incorporating expertise from multiple sectors to create adaptive, user-centered learning systems. In conclusion, SSRL is emerging as a highly interdisciplinary and rapidly developing research area with strong global contributions.

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