Kashihara, A. et al. (Eds.) (2024). Proceedings of the 32nd International Conference on Computers in Education. Asia-Pacific Society for Computers in Education

The Trends in Computer-Supported Virtual Reality Collaborative Learning

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Abstract: The integration of computer-supported virtual reality (VR) in collaborative learning environments is rapidly evolving, presenting new opportunities and challenges for educators and learners. This paper examines the current trends and developments in VR-enhanced collaborative learning, focusing on the technological advancements, pedagogical strategies, and educational outcomes. Through a comprehensive review of recent studies and practical applications, we identify key factors that influence the effectiveness of VR in fostering interactive and immersive learning experiences. The findings highlight the potential of VR to enhance student engagement, improve spatial understanding, and facilitate experiential learning. Additionally, the paper discusses the implications of VR for future educational practices and suggests areas for further research to address the existing limitations and optimize the use of VR in collaborative learning settings.

Keywords: Collaborative learning, Computer-supported collaborative learning (CSCL), Cooperative learning, Virtual Reality.

1. Introduction

The advent of virtual reality (VR) technology has opened new frontiers in the field of education, particularly in collaborative learning environments (van der Meer et al., 2023). As digital natives become increasingly prevalent in the student population, there is a growing demand for innovative teaching methods that leverage advanced technology to enhance learning experiences (De Back et al., 2020; Webb et al., 2022). Virtual reality, with its ability to create immersive and interactive environments, offers a promising solution to meet this demand (Asad et al., 2021).

Computer-supported collaborative learning (CSCL) has long been recognized for its potential to improve educational outcomes by facilitating communication, cooperation, and shared knowledge construction among students (Kaliisa et al., 2022). The integration of VR into CSCL represents a significant evolution in this field, providing unique opportunities for experiential learning and engagement (Petersen et al., 2023). Unlike traditional collaborative learning methods, VR allows learners to interact with three-dimensional environments and objects, enabling a deeper understanding of complex concepts and fostering a sense of presence and immersion.

This paper explores the current trends and developments in computer-supported virtual reality collaborative learning (VRCL). By examining recent research and case studies, we aim to provide a comprehensive overview of how VR is being utilized to support collaborative learning, identify the benefits and challenges associated with its implementation, and suggest future directions for research and practice. The discussion will encompass various aspects of VRCL, including technological advancements, pedagogical strategies, and educational outcomes, offering insights into how VR can be effectively integrated into educational settings to enhance collaborative learning experiences.

In the following sections, we will delve into the key trends driving the adoption of VR in collaborative learning, analyze the impact of VR on student engagement and learning outcomes, and discuss the implications for educators and institutions. Through this examination, we hope to contribute to the ongoing discourse on the role of emerging technologies in education and provide valuable guidance for stakeholders looking to leverage VR to create more dynamic and effective learning environments.

2. Research results

Through a systemic analysis of popular articles on CSCL (Computer-Supported Collaborative Learning) from 2000 to 2024, using keywords such as “Computer,” “Virtual Reality,” “Collaborative,” and “Learning” in the Web of Science (WoS) database, we retrieved 37 articles categorized under Web of Science Categories: Education Educational Research or Education Scientific Disciplines. This analysis yielded significant findings.

Economou et al. (2000) were the earliest to propose the concept of Computer-Supported Virtual Reality Collaborative Learning. Their research demonstrated that integrating virtual participants into collaborative learning environments can significantly impact student outcomes and learning experiences. Economou et al. (2000) indicated that collaboratively creating educational digital artifacts in virtual reality (VR) environments enhances student engagement, motivation, and learning outcomes. Additionally, collaborative virtual environments for interactive learning offer students opportunities to visualize complex scenarios, interact with peers, and enhance creativity and collaboration. The successful development and implementation of virtual learning environments (VLEs) can positively influence academic performance, student engagement, and satisfaction.

The primary finding of this study is that as early as 2000, scholars were already exploring VR, with Economou et al. (2000) highlighting the importance of effectively utilizing technology to improve learning outcomes. Their significant contribution lies in proposing the collaborative exploration of geometric concepts in shared VR environments, which benefits learners through structured activity design and moderate realism, effectively promoting collaborative knowledge construction among students.

The analysis also revealed that England and the United States are leading contributors in terms of publication volume, as shown in Figure 1. The article by Lui et al. (2023) is the most cited. Elsevier is the predominant publisher, as depicted in Figure 2. International scholars predominantly publish in the top-tier journal, *COMPUTERS & EDUCATION*, as shown in Figure 3. The institution YUNG TA INST TECHNOL COMMERCE has made significant contributions, as indicated in Figure 4. Liang JS is the most prolific author in this field globally, as shown in Figure 5. The distribution of Web of Science Categories is primarily focused on Education Educational Research, as shown in Figure 6. Analysis of all key words reveals that virtual reality, interactive learning environments, collaborative learning, virtual-reality, and computer-mediated communication are the top occurrences, as shown in Figure 7.

The main focus of the research is on higher education students, who are the most frequently studied participants. Notably, there is significant exploration of collaborative learning strategies in curriculum design, and the popularity of tablets as a discussion topic is evident in the articles. Among the 37 articles, Lui et al. (2023) emphasize the importance of model-based simplified reasoning in immersive VR for learning and understanding complex systems. By integrating advanced visualization methods such as sensitivity analysis and adversarial analysis, immersive VR environments have been shown to enhance knowledge transfer and problem-solving in education, significantly improving users' system design understanding and task performance. This integration helps bridge the gap between complex models and knowledge interpretability.

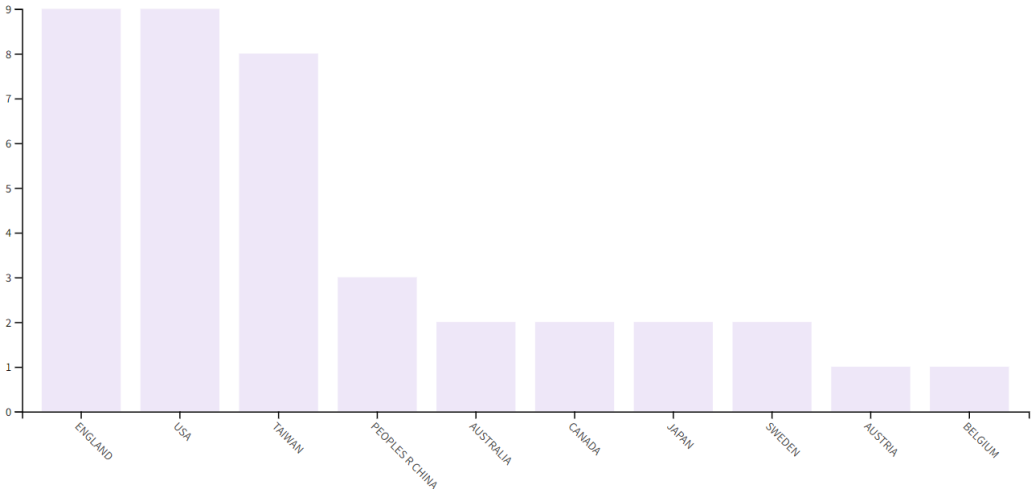

Figure 1. The leading countries.

Figure 2. The most publisher.

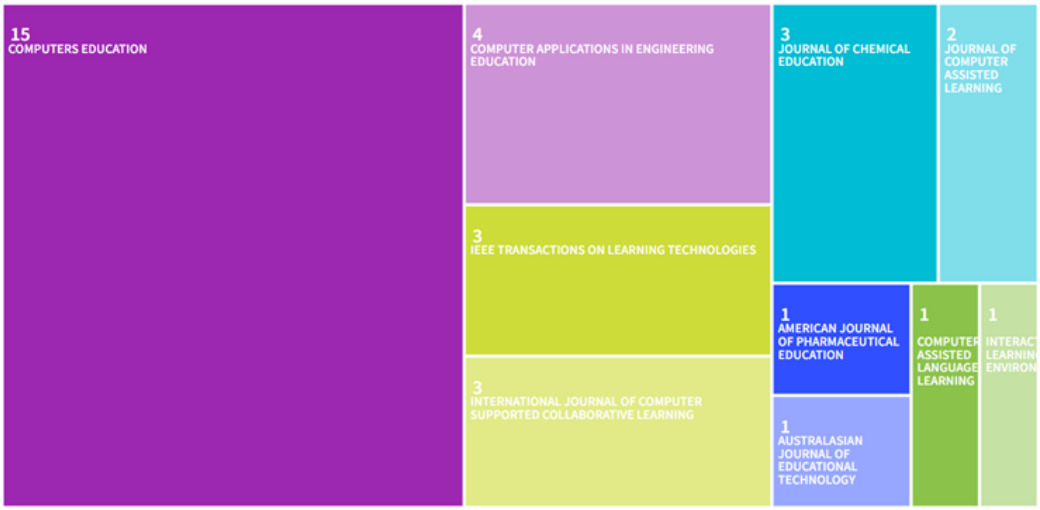

Figure 3. The most published Journal.

Figure 4. The most published institution.

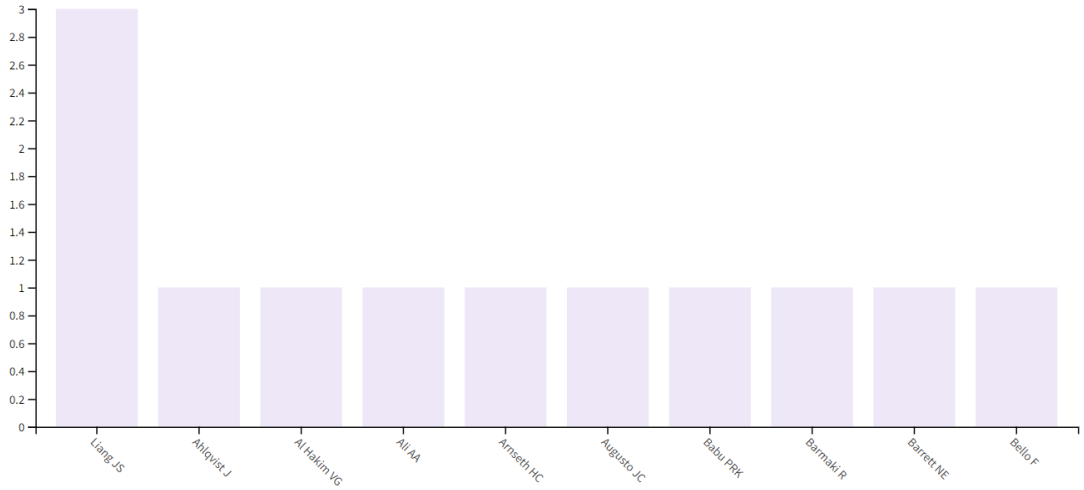

Figure 5. The most published authors.

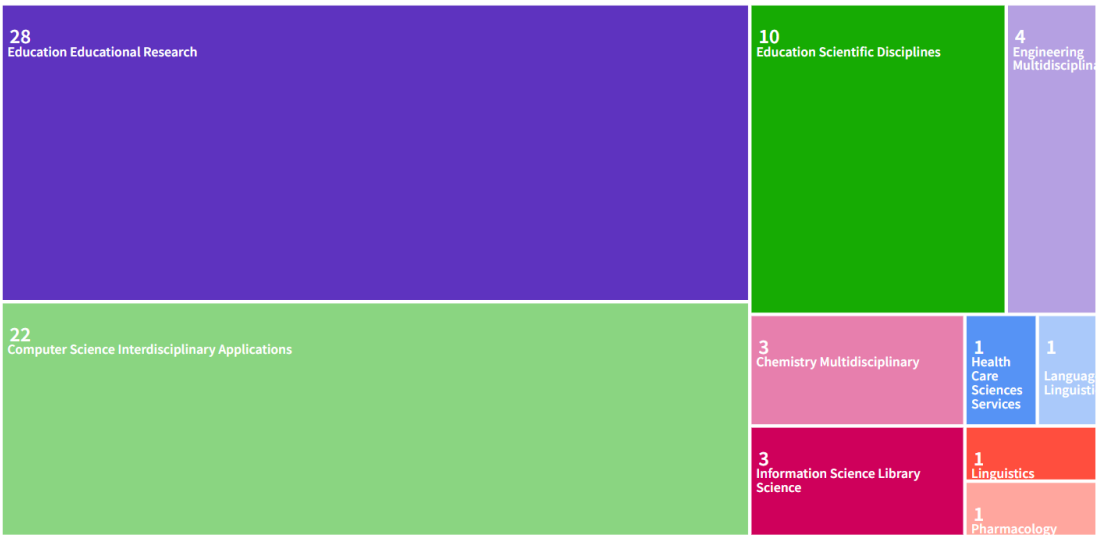

Figure 6. Web of Science Categories.

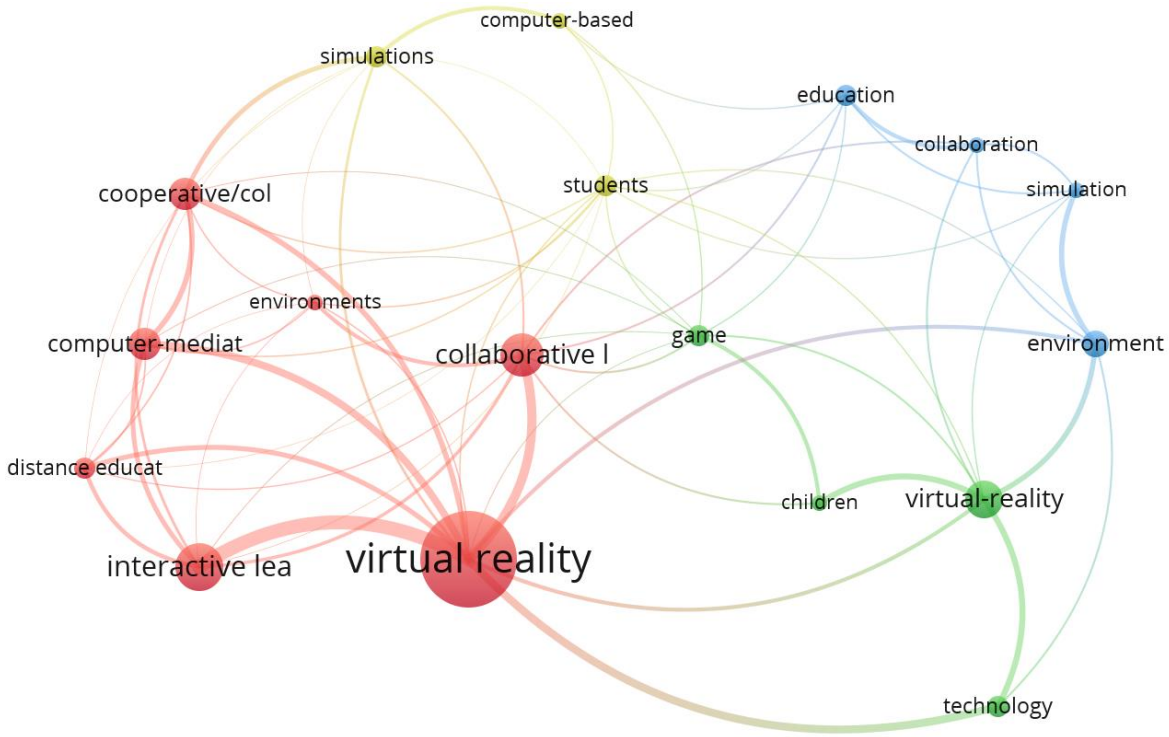

Figure 7. The most published key topics.

3. **Discussion and conclusion**

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One of the primary findings of this study is the early investigation into VR by scholars like Economou et al. (2000), which underscores the importance of effectively utilizing technology to improve learning outcomes. Their significant contribution lies in proposing the collaborative exploration of geometric concepts in shared VR environments, which benefits learners through structured activity design and moderate realism, thereby effectively promoting collaborative knowledge construction among students.

The analysis also revealed that the United States is a leading contributor in terms of publication volume, as shown in Figure 1. The article by Lui et al. (2023) is the most cited. Elsevier is the predominant publisher, as depicted in Figure 2. International scholars predominantly publish in the top-tier journal, COMPUTERS & EDUCATION, as shown in Figure 3. The institution YUNG TA INST TECHNOL COMMERCE has made significant contributions, as indicated in

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In conclusion, the systemic analysis of CSCL literature from 2000 to 2024 underscores the evolution and impact of virtual reality and collaborative learning environments in education. Early research by scholars like Economou et al. laid the foundation for subsequent advancements, emphasizing the importance of technological integration in enhancing learning outcomes. The continuous contributions from various institutions and authors highlight the dynamic and expanding nature of this research field, with significant implications for future educational practices and technological innovations.

Acknowledgments

This study is supported in part by the National Science and Technology Council of Taiwan under contract numbers NSTC 113-2410-H-038-026-MY2, NSTC 112-2622-H-038-002, and NSTC 113-2628-H-007-006.

References

Asad, M. M., Naz, A., Churi, P., & Tahanzadeh, M. M. (2021). Virtual reality as pedagogical tool to enhance experiential learning: a systematic literature review. *Education Research International, 2021*(1), 7061623.

De Back, T. T., Tinga, A. M., Nguyen, P., & Louwerse, M. M. (2020). Benefits of immersive collaborative learning in CAVE-based virtual reality. *International Journal of Educational Technology in Higher Education, 17*, 1-18.

Economou, D., Mitchell, W. L., & Boyle, T. (2000). Requirements elicitation for virtual actors in collaborative learning environments. *Computers & Education, 34*(3-4), 225-239.

Kaliisa, R., Rienties, B., Mørch, A. I., & Kluge, A. (2022). Social learning analytics in computer-supported collaborative learning environments: A systematic review of empirical studies. *Computers and Education Open, 3*, 100073.

Lui, M., Chong, K. Y. A., Mullally, M., & McEwen, R. (2023). Facilitated model-based reasoning in immersive virtual reality: Meaning-making and embodied interactions with dynamic processes. *International Journal of Computer-Supported Collaborative Learning, 18*(2), 203-230.

Petersen, G. B., Stenberdt, V., Mayer, R. E., & Makransky, G. (2023). Collaborative generative learning activities in immersive virtual reality increase learning. *Computers & Education, 207*, 104931.

van der Meer, N., van der Werf, V., Brinkman, W. P., & Specht, M. (2023). Virtual reality and collaborative learning: A systematic literature review. *Frontiers in Virtual Reality, 4*, 1159905.

Webb, M., Tracey, M., Harwin, W., Tokatli, O., Hwang, F., Johnson, R., ... & Jones, C. (2022). Haptic-enabled collaborative learning in virtual reality for schools. *Education and Information Technologies*, 1-24.