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A LITERATURE REVIEW OF COLLABORATIVE VIRTUAL ENVIRONMENTS: IMPACTS, DESIGN PRINCIPLES, AND CHALLENGES

Oumaima Derouech *	National School of Applied Sciences, University of Chouaib Doukkali, EL Jadida, Morocco	derouech.oumaimaa@gmail.com
Hamid Hrimech	Ensa Berrechid - Hassan I University, Berrechid, Morocco	hamid.hrimech@uhp.ac.ma
Mohamed Lachgar	Chouaib Doukkali University of El Jadida, El Jadida, Morocco	lachgar.m@ucd.ac.ma
Mohamed Hanine	Chouaib Doukkali University of El Jadida, El Jadida, Morocco	hanine.m@ucd.ac.ma

* Corresponding author

ABSTRACT

Aim/Purpose	The purpose of this research is to evaluate the available literature on Collaborative Virtual Environments (CVEs). It aims to investigate the impacts, guiding principles, and problems of CVEs, giving light to their revolutionary potential in a variety of sectors, such as education, healthcare, and gaming.
Background	CVEs have received a lot of interest in recent years because of their potential to change how people interact and cooperate in virtual settings. It has the potential to increase collaboration, learning experiences, and productivity across numerous areas.
Methodology	This study comprehensively analyzes existing literature on CVEs, highlighting their ability to significantly change several fields, such as education, healthcare, and gaming. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards were followed to ensure a clear and methodical approach to the literature review. The search technique targeted the SCOPUS database for articles published from 2009 to 2022, utilizing specific keywords about CVEs. This was followed by a thorough two-stage screening procedure

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	based on specified inclusion and exclusion criteria, ensuring only relevant research was evaluated.
Contribution	This literature review contributes by providing a thorough review of the current state of the art in the field of CVEs. It synthesizes previous research and offers insights into the consequences, guiding principles, and problems of CVEs in different domains.
Findings	The research results demonstrate the wide range of uses for CVEs and their ability to promote enhanced cooperation, learning, and productivity. Current obstacles have been identified, and a set of guiding principles for implementing CVEs has been provided. A clear and reproducible foundation for future research in this area was found through a detailed explanation of the search approach and criteria used to select studies. The literature review concludes with practical suggestions for practitioners in many fields, emphasizing the need to consider CVEs to improve cooperation and productivity.
Recommendations for Practitioners	To improve cooperation and productivity, CVEs should be considered by practitioners in education, healthcare, gaming, and industry. Best practices and recommendations for the successful usage of CVEs in various areas must be established. End-user training and assistance are critical for maximizing the benefits of CVE technology.
Recommendations for Researchers	Additional study is required to investigate the long-term consequences and durability of CVE solutions, the creation of new technologies and methods to overcome the stated CVE adoption problems, and multidisciplinary collaboration to harness CVEs in innovative ways.
Impact on Society	The review emphasizes CVEs' potential social benefit in fostering cooperation, improving learning experiences, and increasing productivity. The widespread use of CVE technology may result in more efficient and productive ways of communicating and working in virtual worlds.
Future Research	Future studies in this field should concentrate beyond the study's period (2022), investigating the changing environment of CVEs, examining the effects of developing technologies and trends on CVEs, and evaluating CVE technology's scalability and accessibility for greater societal usage.
Keywords	collaborative virtual environments, collaboration, virtual reality, remote work, education

INTRODUCTION

Collaborative virtual environments (CVEs) are immersive three-dimensional spaces where participants can communicate, share objects, and accomplish various tasks together (Pope et al., 2017). CVEs allow remote people to participate and interact in a virtual world. By sharing access to this digital space, team members can collaborate seamlessly from anywhere globally (Khalid et al., 2021). Indeed, through a virtual reality (VR) system, individuals may collaborate and communicate with one another in real-time while often connecting from faraway areas, successfully bridging geographic distances (Hrimech & Merienne, 2010).

The use of CVEs has become popular in many fields, including military training programs, emergency preparedness simulations, online games, medicine, and many others (Boukerche et al., 2010). To provide a successful and usable experience for participants in CVEs, it is essential to offer an

immersive experience. This immersive experience ensures that participants feel fully present in the virtual environment and think they interact with real people (Casanueva & Blake, 2000).

The growth and widespread adoption of CVEs represent a notable advancement in the way people and institutions engage, cooperate, and accomplish shared objectives in many industries. CVEs, immersive three-dimensional places that allow users to interact, exchange items, and collaborate on projects in real-time, have attracted significant attention due to their ability to overcome geographical constraints and improve distant cooperation. The importance of CVEs has been highlighted by the worldwide transition to remote work and digital engagement, a development accelerated by the COVID-19 pandemic (García-Avilés, 2021).

The idea for this study and the selection of the research topics addressed in this publication stems from the necessity to address significant concerns in CVEs. It performs a comprehensive examination of existing literature on CVEs, specifically emphasizing their effects, guiding principles for their creation, obstacles encountered, and the wider consequences of their implementation in many sectors like education, healthcare, and industry.

The authors acknowledge the difficulties presented by the absence of visible indications and features in virtual environments, which could hinder productive collaboration. In real-life situations, operators vary their behavior in response to their surroundings, such as knowledge of their physical environment, their partner's position, and shared objects, facilitating better collaboration. However, in CVEs, some physical characteristics become unavailable, which makes collaboration more difficult. Then, maps, visual clues, directional sound signs, illumination alterations, compass assistance, and other strategies are used to overcome this issue (Khalid et al., 2019). Virtual worlds, which grew from simple simulations to advanced landscapes, offer immersive experiences where users may explore, interact, and receive multimodal input, enhancing language acquisition (Tseng et al., 2020).

The notion of presence, or the psychological experience in which the user feels physically present in a virtual environment despite being in a different physical location, plays a crucial role in creating an immersive environment in CVEs. This immersion creates the experience of "being there" by activating numerous senses, including sight, hearing, and touch (Park et al., 2019).

This paper provides a thorough analysis of CVEs and how they affect teamwork across a variety of fields. The primary goal of this research is to assess and analyze the scientific literature on CVEs to give new insights into how research in this field is progressing. The rising interest in CVEs across various fields is attributed to their ability to facilitate remote cooperation and address the challenges they present. Additionally, the paper intends to determine the typical concepts employed in CVE creation, the difficulties experienced when putting CVEs into practice, and the possible effects they may have on user participation. This literature review provides an overview of the impact of CVEs in encouraging cooperation by combining data from multiple sources, illuminating future studies and growth in this field.

Interest in CVEs to increase user collaboration and involvement in virtual environments has developed over the last decade (Cottone et al., 2009). Network service quality is vital for facilitating effective cooperation by preserving shared mental models among participants. Network disturbances, such as latency and packet bursts, might impair these common understandings, hurting the user experience and task performance. Ensuring high-quality network conditions is essential for the accomplishment of collaborative tasks within these virtual environments, illustrating the necessity of robust and dependable connectivity in supporting seamless collaboration (Milef et al., 2021).

This work aims to evaluate the literature related to CVEs produced between 2009 and 2022 to gain insights into the field's current advancements, trends, and discoveries. A comprehensive search of the SCOPUS database was conducted to find relevant publications. The poll included precise phrases, such as "collaborative virtual environments" and "collaborative virtual environments applications," to ensure the search parameters were clear. Only peer-reviewed papers published in English

between 2009 and 2022 were considered. The PRISMA framework was used to compare 44 papers that matched the inclusion criteria. These chosen examples included a wide range of CVE applications, including dispersed collaboration, virtual environments, collaborative design, and virtual teams.

Over the study period, major changes have been made in the patterns of CVE research. Early research concentrated mostly on technical details and usability assessments. However, there has been a clear change in recent years toward a stronger emphasis on social dynamics, user behavior, and user-centered design, all with the goal of facilitating more natural and effective collaborative interactions (Park et al., 2019).

Collaborative learning in virtual environments is crucial for generating knowledge and improving interpersonal skills. It involves rigorous preparation and dynamic group formation to facilitate efficient collaboration. Integrating daily technology tools promotes student involvement and autonomy, requiring a change towards interactive and learning techniques. This approach underlines CVE's ability to affect learning outcomes significantly, increasing active engagement, critical thinking, and deeper knowledge through group efforts (Herrera-Pavo, 2021).

Social Presence Theory suggests that the efficiency of a communication tool depends on its capacity to express the presence of others, facilitating close and instantaneous connections. This theory is especially applicable to CVEs since it emphasizes the significance of building CVEs in a manner that improves the feeling of coexistence with others in a communal place. By cultivating a robust feeling of social presence, CVEs have the potential to greatly enhance the caliber of distant collaboration, resulting in more intimate and captivating encounters. This theoretical framework proposes that investigations of CVEs should not concentrate solely on technological functionalities but also on how these environments facilitate social cues and interactions that enhance a more comprehensive and engaging collaborative encounter (Kreijns et al., 2022).

The use of Constructivist Learning Theory in the context of CVEs shows promise, as it highlights learning as an active and creative process where learners build upon their existing knowledge to create new understandings. These environments offer a dynamic platform for constructivist learning by allowing learners to engage with the virtual world and one another, conduct experiments in a safe context, and contemplate their experiences. The immersive and interactive character of CVEs facilitates the constructivist method by enabling learners to interact directly with learning materials, hence promoting a more profound comprehension and retention of knowledge. Future research in CVEs might investigate methods to improve these settings to enhance constructivist learning principles, hence promoting more efficient and captivating educational experiences (Han & Resta, 2020).

Immersive three-dimensional spaces, known as CVEs, have evolved from specialized uses to be essential in other areas, including education, healthcare, and gaming. This transformation has been fueled by developments in VR and AR technology. This transition is emphasized by the growing need for remote collaboration tools, a trend that has been expedited by global events like the COVID-19 pandemic. These occurrences have brought attention to the importance of strong digital platforms that can facilitate intricate interactions across long distances. Although CVEs are becoming more common and have many advantages in improving collaboration, learning, and productivity, they nevertheless have ongoing difficulties in terms of technical accessibility, user experience design, and the incorporation of new technology. These concerns, together with the fast-paced expansion of the digital ecosystem, create a rich field for research. This study intends to fill these gaps by exploring the impacts, guiding principles, and problems of CVEs, contributing to the greater knowledge and development of these virtual spaces. Through this effort, the goal is to enrich the scholarly debate around CVEs and inform practical applications and future technology advancements in this space.

Despite advances in CVE research, significant gaps remain. For example, there has been less attention on integrating CVEs with other developing technologies like artificial intelligence and augmented reality (AR) (Chen et al., 2021). Furthermore, issues of system scalability have gotten little attention. Notably absent is a comprehensive assessment of the impact of CVEs on cooperation and

organizational productivity. Indeed, a review of relevant studies emphasizes the importance of CVE in facilitating collaborative interactions and their potential impact on numerous fields. The major goal of this effort is to investigate novel ways to improve CVE design and to fill identified research gaps by synthesizing current material.

The progress made in VR and AR technology has increased the potential and uses of CVEs, leading to a reconsideration of their impact on collaborative work and learning environments. CVEs build enormous, graphically rich digital worlds where people may come together, engage, and work. Within these broad digital areas, users may exchange and alter information individually and as a group, making CVEs a valuable tool for communal work and engagement (Schäfer et al., 2022).

Research on CVEs is guided by numerous major theoretical principles and ideas, concentrating on boosting the efficiency and efficacy of cooperation in virtual environments. These include the examination of cognitive elements of creative cooperation, the use of 3D material in educational contexts, and the enhancement of spatial abilities using immersive virtual reality.

Design Collaboration in Immersive Virtual Environments (ImVE): The current study underlines the need for further studies on ImVE assistance for design collaboration, particularly during the early design stages. The purpose is to increase thinking, engage, and exchange design thoughts early on since good cooperation at this point can lead to fewer difficulties in later stages. There is a request for additional cognitive study on design collaboration in ImVE to understand how architects cooperate from a cognitive standpoint, perhaps merging design and neuroscience views for deeper insights. The development of new ImVE technologies with enhanced design capabilities is also underlined as a requirement to better assist design during cooperation (Yu et al., 2022).

Educational Applications of CVEs: The use of CVEs in educational contexts is rising, with a particular focus on the function of 3D material. Despite its popularity, issues such as a lack of empirical studies for creating educational activities in 3D CVEs and the absence of conventions for supporting and measuring learning with such technology exist. A suggested technique tries to solve these challenges by promoting collaborative work with 3D content in education based on constructionism and social constructivism ideas. This technique provides a systematic framework for planning educational programs utilizing collaborative work with 3D material (Mironova et al., 2016).

Improvement of Spatial Skills via Immersive Virtual Environments: Research reveals the promise of collaborative immersive virtual environments in developing spatial skills, which are vital across numerous sectors, including STEM education. A study revealed considerable improvement in spatial abilities among individuals engaged in model-building activities within a collaborative virtual world. This shows that spatial training in such contexts might be an effective technique (Conesa et al., 2023).

The study on CVEs is broad and complex, covering the subtleties of cooperation in virtual environments from cognitive, pedagogical, and skill-development perspectives. The continuing creation of more complex and intuitive virtual environments, together with a complete methodology for their application, is a primary focus of the current study.

In the developing environment of digital collaboration, CVEs have emerged as a vital technology, uniting the realms of VR and AR to create immersive venues for distant engagement. Central to the success of CVEs is the notion of social presence, which enables a sense of closeness and immersion among users, hence increasing collaborative experiences across multiple industries, including education, healthcare, and gaming. These settings are further extended by concepts from constructivist learning theory, arguing for active interaction and knowledge-building inside virtual worlds. This combination of modern technology and educational philosophy not only takes CVEs to the forefront of creative learning and collaborative practices but also challenges established boundaries of engagement, cooperation, and productivity. With the incorporation of developing technologies such as artificial intelligence and the Internet of Things (IoT), CVEs continue to reinvent the possibilities for

digital collaboration, suggesting a transformational shift in how we connect, learn, and interact in an increasingly virtual environment.

This literature review uses a comprehensive search technique precisely tailored to capture the range and depth of literature on CVEs. Employing an in-depth analysis of the SCOPUS database, the strategy is anchored by an array of carefully selected terms linked to CVEs, encompassing literature from 2009 through 2022. This thorough selection approach guarantees an extensive assemblage of materials, which is important for an entire study of the area. By complying with the PRISMA standards, the methodology not only offers openness and rigor but also allows replication and consistency in the synthesis of findings.

This paper delves into the complexities of CVEs, starting with an analysis of their evolution and current usage across various industries. It then details the methodology employed in the investigation, emphasizing the systematic approach adhered to PRISMA principles. Subsequently, the findings and analysis are examined, revealing the impacts, challenges, and potential of CVEs. This culminates in a comprehensive conclusion that encapsulates the study's findings and their significance for future research and application in the CVE field.

METHODOLOGY

The main objective of this paper is to provide a comprehensive and unbiased summary of the existing academic literature on CVEs according to PRISMA 2020 guidelines. To ensure transparency and methodological rigor in the study, it is necessary to clarify the rationale behind choosing the specific research questions that will guide the inquiry, as well as to justify the selection criteria for the study.

To ensure a comprehensive and rigorous review of the existing literature, the Scopus database was selected for its wide coverage across disciplines, stringent journal selection criteria, and inclusion of a diverse range of high-quality, peer-reviewed articles from key repositories. This database comprises a wide range of subjects and includes articles from significant sources, such as IEEE Xplore, ACM Digital Library, and ERIC, assuring access to relevant material. Its powerful indexing capabilities enable the fast elimination of duplicates, boosting data quality. Moreover, Scopus' worldwide reach, indexing papers from multiple geographies and languages, gives a broad viewpoint crucial for collecting differing approaches and ideas. Scopus is differentiated by its user-friendly interface and advanced search functions, enabling accurate searches and rapid literature retrieval. This, paired with its ongoing updating system, assures the inclusion of the newest research results, making the review current and relevant. The citation monitoring function inside Scopus further assists in finding key works and analyzing the field's growth, highlighting seminal articles, and developing trends. The quality assurance in journal selection and the database's vast coverage, coupled with sophisticated features, places Scopus as an optimum resource for undertaking a review that is both comprehensive and representative of the highest standards of academic rigor.

The Scopus database is used as a source of papers published between 2009 and 2022. A list of research questions (RQs) has been drawn up, which the literature review aims to answer to secure the study. The selection of research questions, as presented in Table 1, was carefully chosen to cover essential features of CVEs. RQ1 analyzes the many uses of CVEs across multiple disciplines, whereas RQ2 investigates the findings linked to the influence of CVEs on team performance. RQ3 investigates the features inside CVEs that promote dispersed interaction and remote collaboration, as well as their efficacy for virtual cooperation, while RQ4 explores the design and implementation of CVEs to improve user experiences and collaboration results. These research topics were chosen to encompass the most important elements of CVEs. They were judged relevant to the study based on current knowledge gaps in the literature and the interests of scholars and practitioners in this field.

The following Scopus Database research query was used:

Research query = (TITLE-ABS-KEY (collaborative AND virtual AND environments) AND (LIMIT-TO (EXACTWORD, “Collaborative Virtual **Environment**”)) OR (LIMIT-TO (EXACTWORD, “Collaborative Virtual **Environments**”)))

Table 1. Study research questions

No.	Research questions
RQ1	How are emerging technologies within CVEs transforming traditional uses in different fields, and what new applications are being explored?
RQ2	What specific features of CVEs most significantly affect team dynamics and performance in remote and hybrid work environments, considering diverse teams and industries?
RQ3	In what ways do interaction modalities (e.g., VR, AR, mixed reality) within CVEs facilitate or impede effective remote collaboration, and what best practices have emerged for their implementation?
RQ4	How can the design and implementation of CVEs improve both user experiences and collaboration outcomes?

A comprehensive set of inclusion criteria (IC) and exclusion criteria (EC) was used in the selection process of relevant studies to conduct a rigorous literature review of the impact of CVE. The selection criteria were developed to ensure that the most relevant and up-to-date research was included in the literature review. The span of 2009 to 2022 was chosen to encompass the most current breakthroughs in CVE research, corresponding with the most recent studies and technology improvements. To guarantee uniformity and accessibility to a larger audience, the analysis was confined to English-language publications. The exclusion criteria indicated in Table 2 were chosen to focus the review on certain subject areas such as e-learning, autism, training, data visualization, and energy. These areas were eliminated because they deviated from the core goal of the research and prevented us from maintaining a clear and focused methodology. Document categories not subject to peer review or those not presenting novel research findings, such as editorials, opinions, or grey literature, were excluded. This ensures that the review is based on authenticated and academic research publications and guarantees that the review is based on authenticated and academic research publications.

Table 2. Inclusion criteria (IC) and exclusion criteria (EC)

No.	Criteria
IC1	Works published between 2009 and 2022
IC2	Works published in English
IC3	Document type (only articles were included)
EC1	Document type (not peer-reviewed)
EC2	Title and abstract
EC3	Subject area (e-learning, autism, training, data visualization, energy)

The literature review, including the selection of publications from 2009 to 2022, choice of peer-reviewed articles, and concentration on English language papers, were carefully chosen to ensure contemporary relevance and high academic standards. Inclusion and exclusion criteria were rigidly implemented to maintain a clear focus on the major issue of CVEs and ensure that all research included was directly relevant and helpful to the research questions. Such meticulousness in decision-making guaranteed that the review process was methodologically sound and purpose-driven, improving the validity and reliability of the synthesized findings on CVEs.

By providing this explanation for these research questions and selection criteria, the methodological rigor of work can be highlighted and show why these choices are relevant to the thorough analysis of CVEs. Furthermore, following the PRISMA 2020 principles demonstrates the commitment to transparency and a rigorous approach throughout the literature review.

Figure 1 illustrates the identification of a total of 875 documents from Scopus databases. Through the application of EC, articles published outside of 2009 to 2022 and those not written in English were removed, resulting in 388 remaining articles. The number of papers has been reduced to 107 after eliminating conference papers, book chapters, reviews, and books. One duplicate paper was removed. Subsequently, 31 articles were excluded based on title analysis, and 19 were eliminated after abstract analysis. Finally, 5 of the remaining 57 articles were excluded due to their focus on e-learning, data visualization, and energy. The literature review ultimately included 44 articles, as shown in Figure 1.

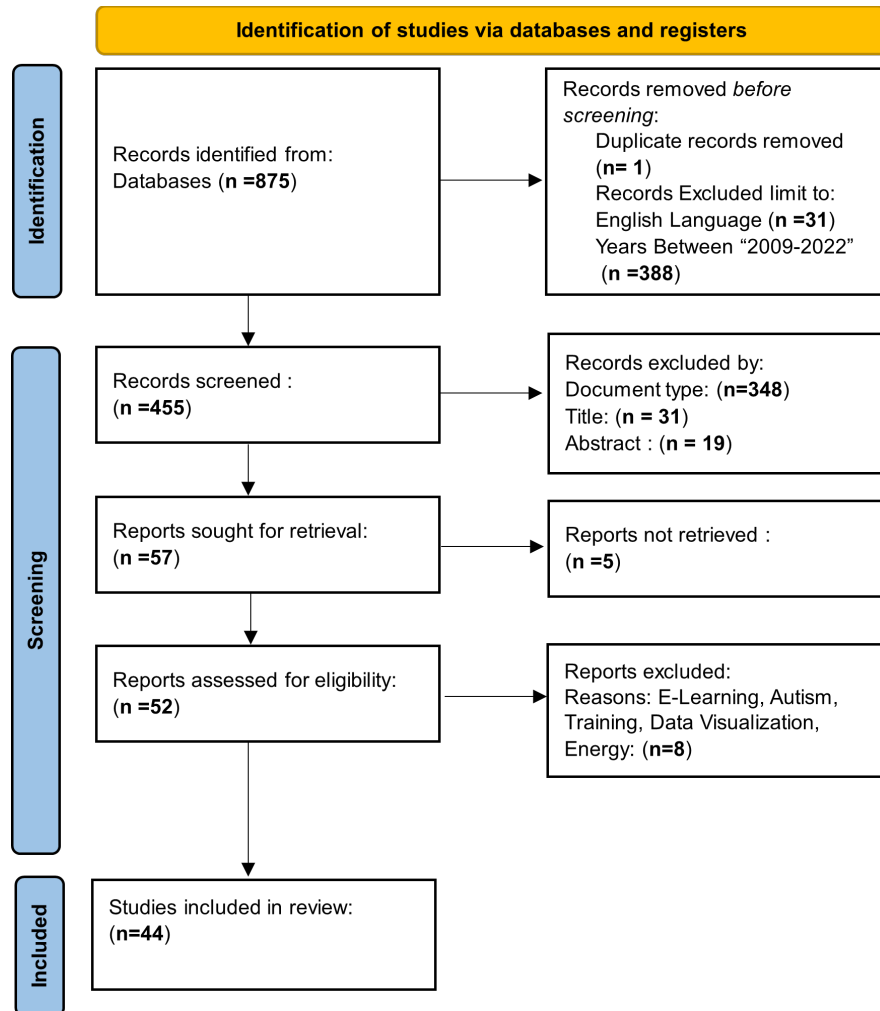


Figure 1. PRISMA flow diagram

The selected studies were thoroughly examined after deciding which papers would meet the predetermined IC and EC. The publication year of each paper, the CVE platforms or technologies used, the types of collaborative activities or applications investigated, and the evaluation metrics used to gauge user experiences and effectiveness were all crucial information extracted.

The CVE platforms' discovered details included a range of technologies, including web-based platforms, AR, and immersive VR, each designed to facilitate a certain type of cooperation. Additionally, various collaborative activities, including collaborative design and instructional situations, were also studied in the trials. These included virtual meetings and shared virtual workplaces.

Additionally, the assessment measures employed in the studies examined addressed user satisfaction, engagement levels, task performance, communication efficacy, and overall collaboration results. The different techniques and results of CVEs were grasped over the review period by methodically collecting and evaluating data.

RESULTS

This section provides a thorough review of the data based on a careful evaluation of 44 papers utilizing the PRISMA technique. Table 3 includes correct citations and a concise summary that details the subject areas covered in each publication. This collection highlights several research endeavors and advances in CVEs. Figure 2 indicates the number of papers published each year.

Table 3. Selected primary studies in the Scopus database

Reference	Subject Area
(Boukerche et al., 2010)	Mobile Ad Hoc Networks
(Steptoe & Steed, 2013)	VR, Human-Computer Interaction, and Data Analysis
(Casanueva & Blake, 2000)	Human-Computer Interaction and User Performance
(Poppe et al., 2017)	Remote Collaboration and Process Diagrams
(Hrimech & Merienne, 2010)	Human Factors and 3D Interaction Metaphors
(Cottone et al., 2009)	Situation Ambiguity, Communication, and Social Interaction
(Lenne et al., 2009)	3D annotations in CVEs
(Radu et al., 2021)	AR and Headset-Based AR Experiences Collaboration
(Gül et al., 2012)	Communication Technologies and Design Activity
(Kunert et al., 2020)	Multi-User 3D Displays and Collaborative 3D Data Exploration
(Khalid et al., 2016)	Task Distribution, User Performance, and Coordination
(Moll et al., 2010)	Haptic Feedback, Audio Feedback, and Collaboration between Sighted and Visually Impaired Individuals
(Roupé et al., 2020)	Immersive VR Systems, Multitouch Table, and Knowledge Sharing
(Hu et al., 2011)	Dynamic Clustering Algorithm and CVEs
(Khalid et al., 2019)	Interaction Techniques, Communication Channels, User Performance, and Guidance Navigation Aids
(Le Chénéchal et al., 2019)	3D User Interactions and Mixed Reality (MR)
(Sharma & Schroeder, 2013)	Distributed Collaboration, Remote Virtual Conference Participation, and Information Technology
(Modugumudi et al., 2013)	Autism, Emotional Recognition, and Assistive Technology
(Erfanian & Hu, 2020)	Multiuser Usability and Verbal and Vibrotactile Cues
(Madathil & Greenstein, 2017)	Remote Moderated Usability Testing and Mixed Methods Experimental Design
(Chopra & Glass, 2012)	3D Input Devices, Synchronization, Gesture recognition
(Chellali et al., 2013)	Spatial Communication, Object Co-Manipulation, Virtual Object Position
(Peña Pérez Negrón et al., 2020)	Avatar-Based Interaction, Nonverbal Behavior, and Automated Interaction Analysis
(Weissker et al., 2020)	Distributed Virtual Environments, Group Navigation, and Remote Collaboration
(Lo et al., 2017)	Human-Human Interaction, Interactive Strategies

Reference	Subject Area
(Collingwoode-Williams et al., 2021)	Avatar-based Interaction, Self-Representation
(Herrera et al., 2018)	Avatar Representation, Behavioral Realism, Nonverbal Behavior, Interpersonal Attraction
(Casarin et al., 2018)	Computer-Supported Cooperative Work (CSCW), Design, Improvements, Networked 3D Environments.
(Ciampi et al., 2010)	Interaction Interoperability, Heterogeneous User Interfaces, Monolithic Applications
(Dubosc et al., 2021)	Avatar Attractiveness, Social Presence, Collaborative Tasks
(Erfanian et al., 2017)	Interaction Models, Conflict Resolution, Multiuser Collaboration, and Satisfaction
(Peña Pérez Negrón et al., 2016)	Collaborative learning and Nonverbal interaction
(Nassiri et al., 2010)	Personal Space Invasion Anxiety, Interaction
(Duval & Fleury, 2009)	Ray-Casting, 2D Pointer, 3D Virtual Ray
(Idrus et al., 2010)	Networked Collaborative Virtual Environments (NCVE), Digital Communication, Collaborative applications
(Felnhofer et al., 2014)	User Perception, Physical and Social Presence
(Becher et al., 2020)	Network latencies in Immersive CVEs
(Gamelin et al., 2021)	Avatars in CVEs and Spatial Communication
(Ratan & Hasler, 2010)	Self-presence in CVEs, Computer-Mediated communication
(Dodds & Ruddle, 2009)	Asynchronous collaboration, Group dynamics
(Wang et al., 2016)	Computer-supported collaborations
(Park et al., 2019)	Immersive VR presence
(Weissker & Froehlich, 2021)	Teleporting in CVEs, Group Navigation
(Voulgari & Komis, 2010)	Collaborative problem solving, online games

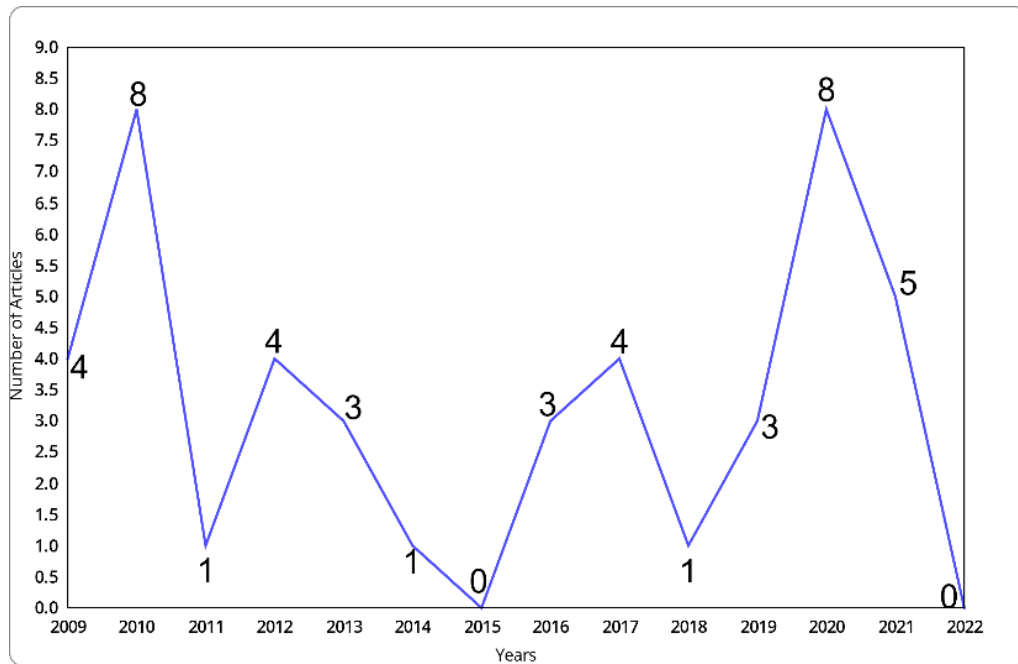


Figure 2. Number of papers published per year

To delve into how the surveyed studies approached the research questions and offer readers a nuanced understanding of the existing literature on the topic, additional precise facts and insights for each research question were provided.

RQ1: HOW ARE EMERGING TECHNOLOGIES WITHIN CVEs TRANSFORMING TRADITIONAL USES IN DIFFERENT FIELDS, AND WHAT NEW APPLICATIONS ARE BEING EXPLORED?

The established remote collaboration solutions are now being used much more frequently. Numerous people now use tools like Microsoft Teams, Zoom, and Cisco Webex. Global organizations and researchers are thus concentrating more on improving distant collaboration techniques to maximize group efficiency. The creation of CVEs brings about issues raised by globalization. These immersive systems let users communicate in a common virtual world while effortlessly joining from their faraway places. The effectiveness of CVE solutions has been demonstrated across several domains, including Design Review, Training, Assistance, and Construction applications (Xie et al., 2021).

Due to the importance of cooperation in many sectors and the benefits of immersive technologies, CVEs have a wide range of applications. These include:

- ***Business:*** CVEs have become essential in the corporate sector for conducting remote meetings and cooperation, particularly in a world where teams are more distant. These environments are distinguished by characteristics such as 3D meeting sets and personalized 3D avatars for each participant. A more in-depth examination of the findings would give insights into how CVEs have revolutionized traditional corporate communication and the specific use cases where they have been most successful (Dodds & Ruddle, 2009).
- ***Engineering:*** CVEs have an important role in engineering methods, particularly in Product Lifecycle Management (PLM) and Building Information Modeling (BIM). Engineers from many sectors work together to create a digital mock-up (DMU), which serves as a shared virtual platform for combining data from multiple disciplines. A closer look at the research in this area can provide insights into the challenges and successes of integrating CVEs into complex engineering workflows, as well as how they have streamlined collaboration (Chellali et al., 2013).
- ***Education:*** CVEs have shown significant educational potential, contributing to the development of motor coordination, physical ability, communication skills, collaboration, and other attributes beyond standard information acquisition. An examination of the research would reveal which educational scenarios have benefited the most from CVEs and how they contribute to a more comprehensive learning experience (Greenwald et al., 2017).
- ***Ongoing Development:*** It is also critical to investigate current advancements in the CVE landscape. Global enterprises are actively attempting to improve remote collaboration technology, including hardware and software. Educational programs such as the “Metaverse Academy” are being created to educate users and developers about the rising relevance of CVEs. The fierce competition among major IT corporations to promote their technology as the premier CVE platform emphasizes the dynamic nature of this industry even more (Becher et al., 2020; Lo et al., 2017).

The CVE application areas keep growing, creating interesting new opportunities across various industries. Global organizations are continually working to enhance remote collaboration technologies, and recently, they have started focusing on the hardware and software that create immersive CVEs. In addition to creating collaborative platforms like Microsoft Mesh, NVIDIA’s Omniverse, and Meta’s Metaverse, these companies have also started educational initiatives like the “Metaverse Academy” to prepare present and future users and developers for the impending CVE age. Because of

this, there is apparent rivalry among major multinational IT firms in promoting their technology as the leading CVE platform (Xie et al., 2021).

Figure 3 shows the most popular areas for CVE environments studied in this article.

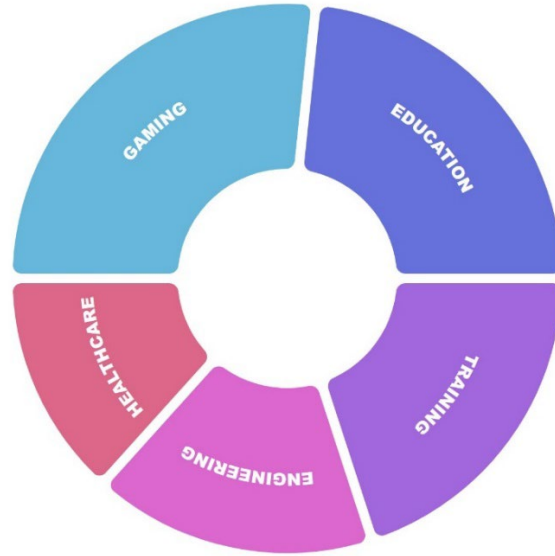


Figure 3. Most popular domains using CVEs in a selection of articles

RQ2: WHAT SPECIFIC FEATURES OF CVEs MOST SIGNIFICANTLY AFFECT TEAM DYNAMICS AND PERFORMANCE IN REMOTE AND HYBRID WORK ENVIRONMENTS, CONSIDERING DIVERSE TEAMS AND INDUSTRIES?

Several variables, including poor coordination, ignorance, or poor communication between cooperating users, may impact user performance. CVEs require avatars, such as a ball, basic virtual hand, sphere, circle, and humanoid avatar (Weissker et al., 2020), and data in various formats, such as audio, video, and text, to handle these problems. Teleconferencing apps use audio data, whereas video conferencing applications use video data. CVEs also use visual, visual, and haptic awareness virtual modalities to increase user support and communication, resulting in better user performance (Khalid et al., 2016).

The research examined several facets of how CVEs affect team performance, and a more complete investigation can provide light on these findings:

- ***The role of avatars:*** The role of avatars inside CVEs is an important consideration. Avatars, which can be human-like or abstract representations, have been studied to see how they affect communication and collaboration. A more in-depth examination would disclose the extent to which avatars impact team dynamics, user engagement, and overall communication efficacy in CVEs (Collingwoode-Williams et al., 2021).
- ***Data forms:*** CVEs use a variety of data forms, including audio, video, and text. Researchers have investigated the effects of several formats on user interactions and cooperation. For example, they may investigate if audio data improves real-time communication while video data improves visual clues. A more in-depth investigation would provide particular facts relating to the usefulness of certain data types in CVEs (Peña Pérez Negrón et al., 2020).

- **Virtual modalities:** CVEs employ a variety of virtual modalities, including visual, aural, and haptic input, 2D pointer, and 3D virtual ray. Researchers have investigated how various modalities increase user assistance and communication, which leads to better user performance. A more in-depth investigation can provide examples of how various modalities are used and their influence on team cooperation (Duval & Fleury, 2009).

Different industries and circumstances may provide different results. A more comprehensive review of the surveyed studies might reveal how the influence of CVEs on team performance differs across industries such as healthcare, education, and business. This would give a more detailed knowledge of how CVEs are tailored to match the specific requirements of each area.

Figure 4 shows the percentage distribution of the different collaborative modalities used in the CVEs studied in this literature review.

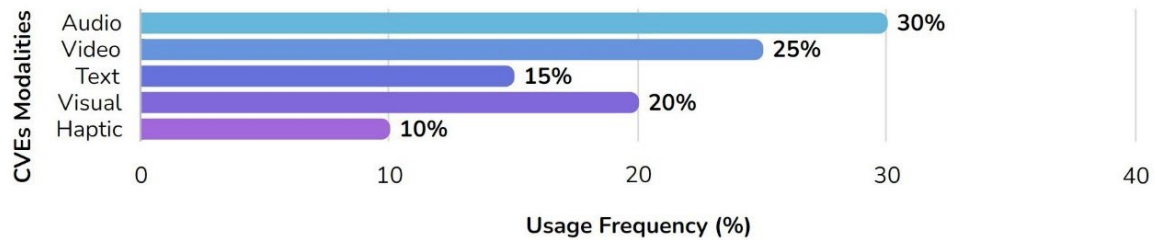


Figure 4. Modalities utilized in CVEs in the studied papers

In addition to emphasizing the advantages of CVEs for team performance, it is critical to discuss the limitations and obstacles. Understanding the restrictions and potential downsides of utilizing CVEs for team cooperation is critical for a balanced perspective. Some studies, for example, may examine technological limits, user adoption hurdles, or possible diversions inside CVEs (Becher et al., 2020).

RQ3: IN WHAT WAYS DO INTERACTION MODALITIES (E.G., VR, AR, MIXED REALITY) WITHIN CVEs FACILITATE OR IMPEDE EFFECTIVE REMOTE COLLABORATION, AND WHAT BEST PRACTICES HAVE EMERGED FOR THEIR IMPLEMENTATION?

To have a better knowledge of RQ3, it is necessary to investigate the features that enable dispersed interaction and remote cooperation in CVEs, as well as how virtual teamwork may be made more successful. The reviewed research highlighted many characteristics and tactics that play an important role in promoting dispersed cooperation, and further investigation could expose these in greater detail:

- **Physical considerations:** The examined study acknowledges the significance of physical factors impacting virtual teams, such as geographic, temporal, and perceived distance. It is critical to investigate how these factors affect virtual cooperation. Geographic remoteness, for example, may alter team dynamics, while temporal issues may include coordinating tasks across time zones. Understanding the subtleties of these factors can give insights into the issues and solutions for CVEs (Morrison-Smith & Ruiz, 2020).
- **Adapting to user environments:** Beznosyk et al. (2010) underline the need to create the CVE system for users' settings, including their roles and gadgets. An examination of this study can reveal how customization and adaptability improve group collaboration and job completion deadlines. Specific examples of how systems might be adapted to user demands would demonstrate the strategy's actual usefulness.

- **Avatars' function:** Avatars have an important function in CVEs and their influence on collaboration. According to research, the existence of avatars may have influenced communication patterns and team cooperation. A thorough examination would give a better understanding of how avatars influence team interactions and which specific design or functionality characteristics are most beneficial (Dubosc et al., 2021).
- **Haptic feedback:** It has been discovered that haptic feedback has a substantial impact on collaborative effectiveness. According to Moll et al. (2010), haptic input is still important for dialog and collaboration, even in circumstances with various perspectives or concealed things. A further in-depth investigation would uncover the exact settings and contexts in which haptic input improves collaboration and communication (Peña Pérez Negrón et al., 2016).

A more extensive examination of the research may offer concrete instances of how distributed teams inside CVEs increased work completion and efficiency because of the identified aspects and tactics. This might contain measurements and data on time saved or productivity enhanced.

RQ4: HOW CAN THE DESIGN AND IMPLEMENTATION OF CVEs IMPROVE BOTH USER EXPERIENCES AND COLLABORATION OUTCOMES?

The development and use of CVEs may greatly improve user experiences and cooperation results. These environments can promote improved user collaboration, communication, and productivity by combining different elements and solving certain issues.

To obtain a better knowledge of RQ4, it is necessary to investigate how the design and execution of CVEs may be enhanced to improve user experiences and collaboration results. The research that was reviewed highlighted several tactics and technologies for accomplishing these improvements, and a more in-depth investigation can provide unique insights into each aspect:

- **Joint motion tracking:** Accurate joint motion tracking can greatly improve CVEs. Precise detection and replication of users' joint motions assist in the creation of realistic and immersive virtual world experiences. The impression of presence and engagement inside the VR is enhanced by detailed tracking. It is critical to investigate the specific technologies utilized for joint motion tracking, the influence on user experiences, and the practical applications of this technology. This virtual experience is captivating, responsive, and mimics user activities (Park et al., 2019). A more in-depth examination of these technologies and tactics, as well as their role in solving specific difficulties, will provide a more complete picture of how CVE design and implementation may revolutionize user experiences and improve collaborative results.
- **User engagement:** The design of CVEs attempts to engage users successfully. A further in-depth review of the research might uncover design concepts and elements that promote user engagement. Gamification components, interactive interfaces, or immersive settings, for example, may capture people and keep them actively interested in cooperation (Ratan & Hasler, 2010).
- **Collaboration tools and features:** Researchers may have looked at developing collaboration tools and features for CVEs. Real-time document sharing, interactive whiteboards, and communication channels are examples of these technologies. A more in-depth examination can reveal tools and features that improve cooperation outcomes and user experiences (Casarin et al., 2018; Ciampi et al., 2010).
- **Seamless integration:** Technology integration is a vital part of CVE design and implementation. Researchers may have discovered how combining several technologies, such as VR, AR, and MR, improves user experiences. Understanding various integration tactics and how

they affect user engagement and cooperation can provide useful information (Le Chénéchal et al., 2019; Radu et al., 2021).

- **User Satisfaction and Productivity:** It is critical to investigate how CVE design and implementation affect user satisfaction and productivity. To measure the success of design decisions, research may involve user feedback, surveys, or performance indicators. A more extensive examination can give specific examples of how to increase customer happiness and productivity (Erfanian et al., 2017).

Figure 5 shows the different forms of CVEs used as solutions in the articles studied in this literature review.

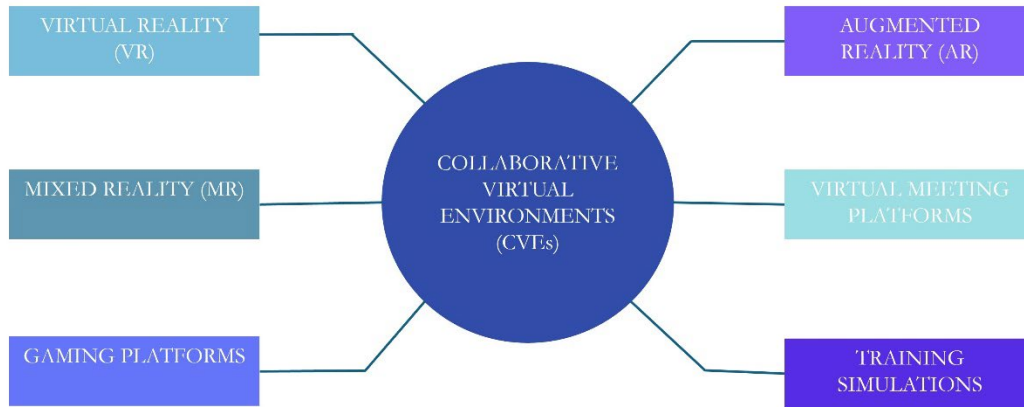


Figure 5. Various forms of CVEs used as solutions in the studied articles

Table 4 presents a structured overview of the contributions made by selected studies in addressing the research questions outlined in the literature review. Each row represents a distinct research subject, providing a concise summary of the main discoveries and emphasizing studies that provide valuable insights. The purpose of this format is to clarify the connection between the research questions and the existing literature, making it easier for readers to understand the impact and implications of CVE research across various domains.

Table 4. Summary of research findings by research question

No.	Key Findings
RQ1	CVEs have been identified as useful tools in several fields, such as education, engineering, commerce, and continuing development. They are particularly valuable for enabling distant cooperation and creating immersive experiences.
RQ2	CVEs optimize team effectiveness by enhancing coordination, facilitating communication, and offering immersive engagement methods.
RQ3	For virtual cooperation to be effective, it is important to consider physical factors, adapt to user surroundings, utilize avatars, and provide haptic feedback.
RQ4	Concentrate on monitoring the movement of joints, including the user, utilizing tools for cooperation, smoothly incorporating different components, and improving user pleasure and productivity.

In conclusion of these findings, the usage of CVEs is increasing, transforming how people cooperate and communicate across several areas. The rising dependence on remote collaboration platforms such as Microsoft Teams, Zoom, and Cisco Webex highlights the growing significance of CVEs in modern business and education.

Through aspects such as joint motion tracking, user engagement, collaboration tools, seamless integration, and user happiness, they have the potential to greatly improve user experiences and collaboration results.

CVEs are influencing the future of collaboration and communication by providing a dynamic platform that improves team performance, user experiences, and how we work and learn across sectors and industries.

In the process of further advancing the academic discussion on CVEs, it is crucial to gather all the current knowledge and analyze its themes and concepts in detail. To achieve this goal, this literature review has utilized the analytical capabilities of Bibliometrix/Biblioshiny to discover the hidden links and thematic strengths within research on CVE. Through an intensive method of mapping the academic landscape, these visual analytics not only reflect previous research but also provide a foundation for generating new theories. They expose the complex network of multidisciplinary connections that combine to create the CVE debate. This preliminary analysis provides a comprehensive framework for this investigation, enabling us to speculate on the future trajectory of CVE research. It helps to find areas of study that have not been extensively studied and are ready for examination, as well as areas with a lot of existing research that may benefit from new views or innovative methods. The subsequent visual depictions, including Treemap, trend analysis, and co-occurrence networks, serve as navigation tools, helping us navigate the intricacies of CVE research and advancing the academic discourse into unexplored areas.

The Bibliometrix/Biblioshiny R package toolbox allowed us to conduct a bibliometric analysis of the 44 papers obtained from the Scopus database. As a result, a quantitative map of the research field of CVEs was created. Through the utilization of the many capabilities of Bibliometrix/Biblioshiny, the information was successfully processed, trend analysis was conducted, and visually compelling data visualizations were generated. These graphs illustrate the distribution of study themes, indicating the range and main areas of academic focus within the landscape of CVEs. By employing Bibliometrix/Biblioshiny, the unprocessed bibliographic data were also transformed into a well-organized and enlightening representation, which added a substantial analytical aspect to this literature review.

Figure 6 visually displays the main themes or categories derived from the selected publications chosen from the Scopus database, with a specific focus on CVE/CVEs. The dimensions of each block are proportional to the number of documents associated with each category, allowing for a rapid visual evaluation of the most and least discussed topics in the dataset.

- **CVE/CVEs:** These are the most significant, accounting for 52% of attention, suggesting that it is a central area of concentration within the dataset.
- **VR:** This is the second-largest area of interest, accounting for 19% of the overall interest. This indicates a notable level of study interest in the virtual reality portion of CVEs.
- **3D Interaction:** This category is fairly represented, with a 5% interest. It indicates a curiosity about how consumers engage with 3D spaces.
- **Social Presence:** Also, with 5% interest, this shows a study interest in how users view others within CVEs.
- **Avatars:** 3% in this category show some attention to the portrayal of users inside these contexts.
- **Awareness:** This factor, at 3%, might relate to how users retain awareness of other users' behavior within CVEs.
- **Collaborative Design:** With 5%, this demonstrates an emphasis on the design side of CVEs for encouraging cooperation.
- **Augmented Reality:** Has 3%, suggesting it is a less important topic but still related to the wider theme of virtual worlds.

- **Collaboration:** With 3%, it's likely to encompass the broad concepts and practices of collaboration inside CVEs.

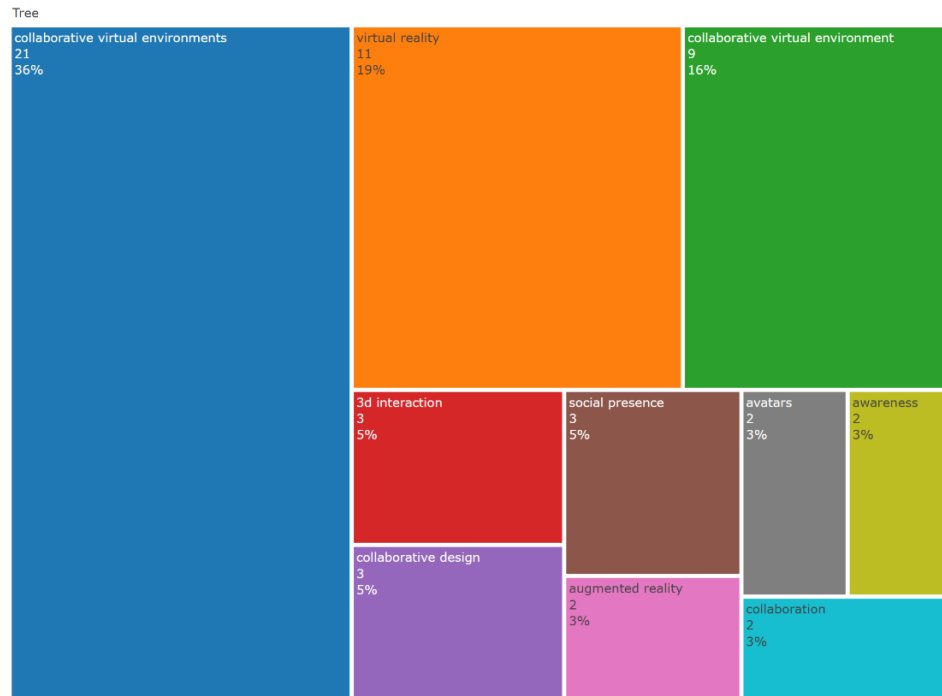


Figure 6. A treemap analysis of research focus

Figure 7 presents a chronological snapshot of the prevailing discourse, illustrating the ebb and flow of specific phrases indicative of the research community's shifting objectives and interests. It emphasizes significant terms – such as “immersive,” “virtual,” and “collaborative” – and monitors their prevalence over the period from 2009 to 2022, presenting a visual narrative of the field's progress. Peaks in word frequency not only identify periods of focused study but also likely coincide with technology developments or significant events impacting CVE research. This visualization serves as a strategic tool for spotting trends and trajectories throughout literature, helping scientists to interpret their results within the greater scholarly debate.

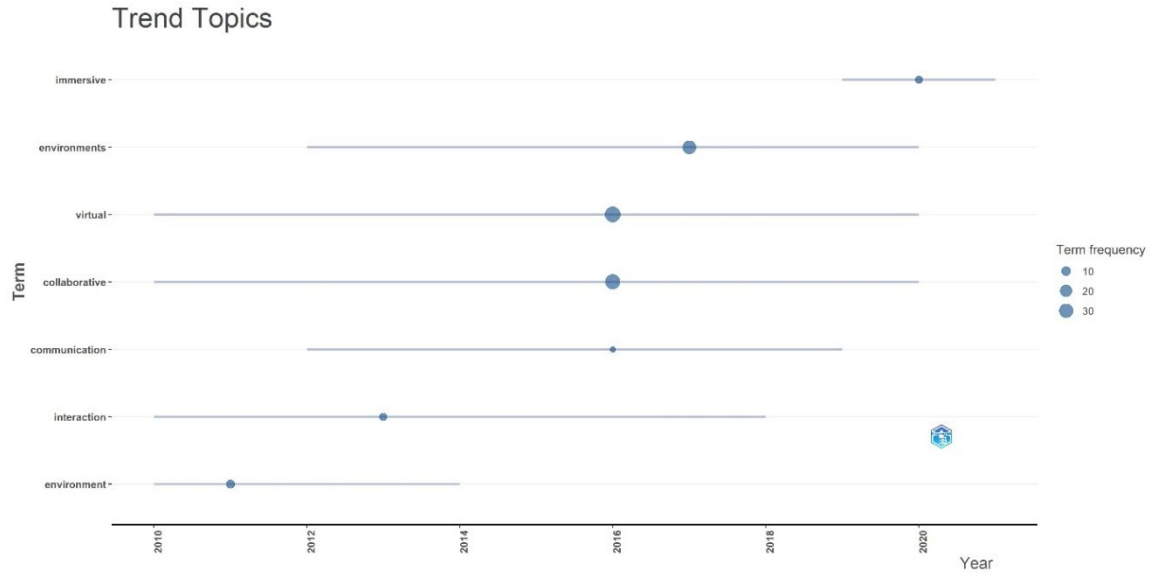


Figure 7. A temporal analysis of key term frequency

Figure 8 shows a co-occurrence network built using the Bibliometrix R tool based on the selected studies on CVEs. It maps out the interconnection of major concepts within the literature, emphasizing the thematic focus and linkages in the topic. The size of the nodes represents the frequency of each phrase's occurrence, while the lines show the strength of the term's occurrence, suggesting thematic relationships. At the center, "CVE" shows as a dominant node, signifying its importance in the research. Surrounding nodes like "virtual reality," "display devices," and "communication" demonstrate the varied yet interrelated components of CVEs study. This network not only delineates the structural structure of present academic debate but also provides a roadmap for recognizing new trends and viable areas for future investigation within the realm of collaborative virtual experiences.



Figure 8. A co-occurrence network map

The graphs generated by Bibliometrix/Biblioshiny play a versatile function in improving the readers' understanding and involvement. They serve as a visual synopsis that enhances understanding of intricate data, outlining the progression of research themes in CVEs and pinpointing crucial patterns. By clarifying both important and less important subjects, these visual aids draw attention to areas where

study is lacking and areas that have not been thoroughly examined, which stimulates the creation of new theories. The rich context provided by these sources enhances this literature review by situating the work within the wider scholarly environment and enabling a cohesive narrative on the evolving dynamics of CVE research. Furthermore, these graphs play a crucial role in organizing the discussion part, providing evidence for the claims made, and directing strategic planning for future investigations. By making bibliometric findings easier to understand, they not only improve the readability of the article but also encourage readers from different fields to explore the complexities of CVE research.

DISCUSSION

The findings of this PRISMA-based literature review provide crucial insights into the domain of CVEs and have substantial consequences for both theoretical understanding and practical implementations. This paper emphasizes the critical significance of social connection and presence inside CVEs, emphasizing how a greater feeling of immersion and co-presence may significantly improve user engagement and collaboration. The findings imply that greater research into the fundamental mechanisms underlying effective partnerships in CVEs is necessary, and ideas such as social presence should be investigated more thoroughly to shed light on these phenomena.

The study does, however, indicate many weaknesses that should be addressed in future research. One significant restriction is the possibility of study heterogeneity within the collected literature, which may have an influence on the generalizability of the results reached. Future studies should consider these differences in technique and conclusions to create a more comprehensive view of CVEs and their impact. This study also highlights the importance of developing new models and frameworks for characterizing and analyzing collaborative behavior in virtual environments, acknowledging that communication and collaboration patterns in CVEs differ dramatically from those in traditional contexts (Herrera et al., 2018).

Furthermore, the research emphasizes CVEs' potential for improving remote cooperation as well as their value in various training and simulation activities such as military training, disaster response training, and medical training. This is consistent with earlier studies on the use of virtual worlds in education and training (Voulgari & Komis, 2010). However, it is critical to recognize that for CVEs to be properly adopted in professional settings, suitable training and assistance are required. This discovery highlights the importance of more studies into the implementation techniques and training methods required to optimize the advantages of CVEs in real contexts (Wang et al., 2016).

To address the constraints and advance the subject, future studies should investigate the long-term effects of CVE implementation on cooperation, learning, and user engagement. Understanding CVEs' long-term effects on these aspects will offer a more complete picture of their efficacy and areas for development. It is also vital to investigate how user experience and interface design correspond with CVE usage to maximize user engagement and involvement. This emphasis on user-centered design aligns with concepts from the study of human-computer interaction, confirming CVE research's multidisciplinary character (Nassiri et al., 2010).

This literature review, driven by the PRISMA framework, seeks to give a complete overview of CVEs, their impacts, guiding principles, and the issues they confront across diverse disciplines. While the technique was supposed to be thorough, it is vital to identify and reflect on the inherent limits of the search strategy.

One noteworthy shortcoming of the search approach was its dependence on a single database, SCOPUS. Although SCOPUS is well renowned for its vast coverage of peer-reviewed literature, the exclusion of other databases could have resulted in the absence of pertinent research published elsewhere. Future studies might alleviate this restriction by including more databases such as PubMed, Web of Science, and IEEE Xplore, assuring a more thorough collection of literature on CVEs. Moreover,

the search keywords were rigorously designed to encompass the entire span of CVE research, yet the fast-expanding vocabulary and various nomenclature connected with virtual environments might mean that some essential studies were mistakenly ignored. Expanding the search phrases and including developing keywords linked to VR, AR, and MR could boost the scope of future evaluations.

Additionally, the literature review was confined by language, concentrating primarily on papers published in English. This language barrier possibly removes useful research and opinions published in other languages, which might give unique insights into the development and deployment of CVEs internationally. Incorporating papers in different languages will surely increase the review's comprehensiveness and worldwide significance.

The findings of this review underline the relevance of CVEs in promoting distant collaboration, boosting learning experiences, and improving productivity. By methodically analyzing material within a set period and following demanding criteria, the study reinforces the relevance of CVEs in transcending geographical barriers and enabling immersive, collaborative experiences. This is particularly crucial in the context of the increased transition towards remote employment and digital engagement driven by global events like the COVID-19 epidemic. The assessment of existing difficulties and the development of guiding principles for CVE implementation led to a clearer knowledge of how to optimize these environments for varied applications.

The synthesis of earlier research with insights into the effects, guiding principles, and problems of CVEs strengthens the academic debate around these settings. It demonstrates the progression of CVE research from relying exclusively on technical and usability assessments to including social dynamics, user behavior, and user-centered design. This change is crucial for promoting natural and productive collaborative relationships inside CVEs. Moreover, the emphasis on multidisciplinary collaboration to utilize CVEs innovatively corresponds with the general trend toward interdisciplinary methods in technology development and implementation.

Despite these limitations, this analysis gives valuable insights into the present status of CVE research, highlighting their potential to transform cooperation and engagement across multiple sectors. By identifying these limitations, the integrity of the findings was reinforced, and it also set a roadmap for future studies to build upon this work, exploring new places within the realm of CVEs.

Considering the comprehensive analysis of CVEs and their wide-ranging applications in education, healthcare, gaming, and more, this document suggests forward-looking hypotheses to expand the current boundaries of understanding and utilization. First, it is hypothesized that integrating artificial intelligence and machine learning into CVEs will revolutionize personalized learning experiences by enabling adaptive learning paths that react in real-time to the needs of each learner, thereby significantly improving educational outcomes. Second, it is predicted that combining CVEs with enhanced biometric feedback systems will substantially advance remote healthcare delivery, facilitating more immersive, accurate, and empathetic patient care practices. This could include virtual reality therapies that adjust to the mental and physical conditions of patients instantly. Third, in the gaming sector, it is anticipated that the future development of CVEs will concentrate on creating deeply immersive and emotionally engaging experiences through haptic feedback and environmental adaptability, promoting a new level of involvement, and diminishing the distinction between virtual and physical realities. These hypotheses aim not only to direct future research efforts but also to encourage the CVE community to explore novel technological integrations that could broaden the capabilities and applications of virtual environments.

This information empowers CVE designers and educators with the insights needed to construct adaptable and engaging virtual environments adapted to varied learning requirements. By understanding the design principles that facilitate remote collaboration, educational professionals may build more dynamic and productive distant learning experiences. The use of CVEs for realistic simulations in domains like healthcare enables practical training that transcends physical boundaries, giving a new paradigm in skill development and professional training. Additionally, recognizing the characteristics

that lead to a sense of presence and involvement in CVEs permits the production of engaging instructional content, hence enhancing student engagement and retention.

It is critical to examine the implications of CVEs on various user groups to maintain inclusivity and accessibility. Investigating how demographic factors impact user interactions and outcomes in CVEs might aid in making these virtual environments more inviting and inclusive. This approach is consistent with the wider debate on technology and diversity, highlighting the need to address concerns of accessibility and equitable use.

Finally, while CVEs provide potential possibilities for cooperation, training, and simulation, they are not without obstacles. Addressing the mentioned limits and doing more research on long-term implications, user experience, diversity, and inclusion are critical to fully realizing their potential and reaping the advantages in practical scenarios. CVEs can become more effective tools for improving human relationships and performance in virtual environments by broadening the field of study and building on existing academic debate.

CONCLUSION

This literature review offers a thorough examination of existing research on CVEs, covering a wide variety of subjects important to both theory and practice. This review's findings are relevant because they accord with and expand the findings of earlier research on this subject. The focus on the importance of social engagement and presence in CVEs is consistent with previous academic discourse in which researchers emphasized the relevance of social presence in virtual settings. This acknowledgment of social presence emphasizes the vital role of human connection in virtual cooperation and communication, strengthening the theoretical underpinnings of the CVE study.

Furthermore, the review's emphasis on the significance of well-designed CVEs in educational and training contexts aligns with previous research that has demonstrated the benefits of such environments in decreasing cognitive loads and improving learning results. Researchers, for example, focused on the potential of virtual environments in educational settings, emphasizing their ability to provide immersive and interactive learning experiences. This agreement with current studies emphasizes the findings' robustness and practical importance.

CVEs have significant practical ramifications, particularly in terms of their ability to facilitate distant cooperation and enhance training and simulation situations. The study acknowledges these practical benefits, echoing earlier research that emphasized the usefulness of virtual environments for training and simulations in a variety of fields. This agreement with previous studies highlights CVEs' real-world relevance in facilitating greater cooperation and learning outcomes.

This review adeptly answers its research questions, delivering logical results anchored in methodical analysis. For instance, it elucidates how developing technologies within CVEs are redefining established usage and investigates new applications, showing the dynamic nature of CVE creation and utilization. The investigation of elements that impact team dynamics and performance in CVEs gives useful insights for building more effective collaborative tools and environments. Additionally, the study's focus on interaction modalities inside CVEs gives information on best practices for their implementation, further guiding the design and usage of these environments.

However, numerous limitations of this study must be acknowledged. Variations in the methodology and findings of the included studies may alter the generalizability of the conclusions, as has been noted in prior work. This restriction highlights the importance of more studies to overcome these disparities and give a more detailed view of CVEs. Furthermore, while the review touches on the implications of user experience and design, a more in-depth examination of the interface and usability variables impacting user involvement in CVEs would be beneficial. The study of human-computer interaction, for example, gives useful insights into how design aspects affect user experiences in virtual worlds.

Future studies could investigate the long-term effects of CVE deployment on collaboration, learning, and user involvement to develop the discipline of CVEs. This longitudinal method can assist in revealing the long-term effects and any developing dynamics connected with CVE use, providing a more complete knowledge of its effectiveness. Furthermore, research on diversity and inclusion within CVEs is critical because it guarantees that these virtual environments cater to a diverse range of user groups by considering the effects of various demographic aspects on user interactions and results. Such openness is consistent with wider concerns about technology and diversity, emphasizing the importance of creating accessible and equal virtual places.

By integrating and expanding current information, this literature review makes an important addition to the area of CVE research. This study fits with and adds to the current academic debate by acknowledging the significance of social engagement, user experience, and practical applications. However, understanding and resolving the constraints through future studies on long-term impacts, user experience, and diversity and inclusion is crucial to unlocking the full potential of CVEs in multiple areas, benefitting both individuals and organizations.

The literature review has built a comprehensive footing in investigating the diverse area of CVEs, encompassing an array of themes crucial for academic inquiry and practical implementation. This analysis, under and enhancing prior research, highlights the critical significance of social contact and presence within CVEs. It reiterates the necessity of building human relationships in virtual collaborations and interactions, reinforcing the conceptual foundations required for ongoing CVE research.

The analysis focuses attention on the crucial function of precisely constructed CVEs within educational and training contexts. This is compatible with past research displaying the usefulness of such settings in lowering cognitive load and boosting learning results. Such academic unanimity highlights the robustness and applicative significance of the findings, highlighting the pragmatic implications of CVEs in promoting distant cooperation and enriching educational and simulation experiences.

The integration of Artificial Intelligence and Machine Learning in CVEs stands as a disruptive way to personalize educational experiences for individual learners, presenting the possibility for dramatically enhanced learning outcomes. The incorporation of advanced biometric feedback technologies can transform remote healthcare education by delivering immersive and sympathetic teaching techniques. For a larger educational impact, establishing profoundly immersive learning experiences using haptic feedback and contextual adaptation can boost engagement and blur the barriers between virtual and real-world learning settings. Ensuring inclusion and accessibility within CVEs is vital to democratize educational advantages among various communities. Lastly, exploiting CVEs for multidisciplinary cooperation can open creative educational applications, stimulate innovation, and widen the boundaries of teaching and learning approaches.

Future research in CVEs is positioned to dig into numerous crucial areas to augment their influence and efficacy across various fields. Key directions include assessing the long-term consequences and durability of CVE solutions to ensure sustainable engagement and benefit, innovating new technologies and methods to address adoption challenges and improve user experience, and fostering multidisciplinary collaboration to unlock novel applications and enhance the functionality of CVEs. Additionally, studying the scalability and accessibility of CVE technologies will be vital to widen their social advantages, making these immersive platforms available to a more varied audience. Integrating CVEs with new technologies like artificial intelligence, augmented reality, and the Internet of Things also gives a tremendous potential to develop more immersive, engaging, and secure virtual environments, marking the next step in collaboration and learning spaces. These research activities are not only crucial for improving discipline but also for achieving the full promise of CVEs in transforming how we cooperate, learn, and engage in virtual environments.

As this comprehensive exploration of CVEs reaches its end, it is essential to realize the inherent limitations of the study provided. The research, comprehensive in its breadth, largely obtained material from the SCOPUS database encompassing papers from 2009 to 2022. This methodological

approach, while rigorous, may have mistakenly excluded significant insights from works outside this era or published in databases beyond the scope of this study, such as WoS or PubMed.

Furthermore, the study was constrained to peer-reviewed journal papers, therefore neglecting the abundance of information included in conference proceedings, books, and book chapters. These sites, packed with varied viewpoints and pioneering research, might potentially expand the knowledge and uses of CVEs.

The dependence on the Bibliometrix R program for bibliometric analysis gave a formal approach to examining the large literature on CVEs. However, the examination of alternative bibliometric tools like BibExcel, HistCite, or Gephi can provide additional aspects of analysis, perhaps uncovering trends and patterns not recorded in the current review. The fast-developing area of CVEs, pushed by developments in VR, AR, and MR, provides a problem and an opportunity for researchers. The dynamic nature of this subject suggests that future advancements might greatly alter the efficacy, design principles, and problems of CVEs in ways not completely covered in the present work. Therefore, future studies should be nimble, widening the area of analysis to encompass developing technologies and their consequences for collaborative virtual environments.

In closing, while this article sheds light on the major significance of CVEs in encouraging collaboration across multiple industries, the limitations indicated pave the way for further studies. By widening the study scope, applying varied methodological approaches, and staying informed of technical changes, further studies can build on these results to further explain the complex, shifting environment of CVEs.

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AUTHORS



Oumaima DEROUECH is currently engaged in doctoral research at the National School of Applied Sciences, University of Chouaib Doukkali, in EL Jadida, Morocco. Her research endeavors revolve around the dynamic realm of information and communication technologies, mainly focusing on collaborative virtual environments, virtual reality, augmented reality, and human-computer interaction (HCI).



Hamid HRIMECH is a professor of computer science at the National School of Applied Sciences of Berrechid in Morocco and holds a PhD from the École Nationale d'Arts et Métiers in France.

His research focuses on collaborative virtual environments and artificial intelligence. He is interested in the potential of shared virtual environments for interaction and collaboration. He also conducts research in artificial intelligence.



Mohamed LACHGAR received a Ph.D. in computer science at the Cadi Ayyad University in 2017. He is a professor of computer science at the National School of Applied Sciences, Chouaib Doukkali University of El Jadida, Morocco. His research interests are in the areas of automation tools development in embedded software, software modeling and design, metamodel design, model transformation, model verification, and validation method, and machine learning and deep learning.



Mohamed HANINE is currently serving as an Associate Professor at the National School of Applied Sciences, University of Chouaib Doukkali, in EL Jadida, Morocco. He holds a Ph.D. in Computer Science, specializing in spatial decision-making. His research primarily focuses on Big Data, Multicriteria Decision Making, NoSQL, and Business Intelligence. In 2017, he successfully completed his Ph.D. in computer science at the University of Cadi Ayyad in Marrakesh, Morocco. Subsequently, in 2018, he joined the Department of Telecommunications, Networks, and Computer Science at the National School of Applied Sciences, where he educates engineering students in the fields of Big Data, NoSQL, and Business Intelligence.