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Exploring the research trends and development of augmented reality and virtual reality in ASEAN countries: a bibliometric study

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ABSTRACT

This review of Association of Southeast Asian Nations (ASEAN) augmented reality (AR) and virtual reality (VR) studies uses bibliometric analysis and VOSviewer mapping. This study looks at an extensive set of Scopus articles from reliable sources to determine who contributes to ASEAN AR and VR research, the themes, how people work together, and how people cite each other. A study of bibliographies shows that the number of ASEAN AR and VR research articles has grown significantly since 2010. It also talks about important ASEAN study institutions, authors, and countries. The study themes are shown visually on VOSviewer mapping, showing how AR and VR can be used in healthcare, travel, gaming, and business. Co-authorship and reference networks shed light on how people work together on research projects and how ideas move within and outside of ASEAN. This organized review of ASEAN AR and VR research helps researchers, policymakers, and business stakeholders understand the current situation, find research gaps, and work together. The results can change research, resource use, and policy changes to encourage the growth and use of AR and VR technologies in ASEAN. It can lead to more innovation, economic development, and positive social effects.

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1. INTRODUCTION

Over the past decade, Association of Southeast Asian Nations (ASEAN) countries have witnessed a significant rise in the use of augmented reality (AR) and virtual reality (VR) technologies across various sectors [1], [2]. Governments and businesses in the region are increasingly recognizing the potential of these technologies to enhance productivity, efficiency, and customer engagement. From virtual training simulations in the manufacturing industry to immersive storytelling in tourism, AR and VR are reshaping the way ASEAN countries approach education, training, and entertainment [3]. These immersive technologies have not only transformed entertainment and gaming but also have profound implications for various industries, including education, healthcare, and tourism. In the ASEAN region, the adoption and development of AR and VR have been steadily increasing, driven by technological advancements and a growing demand for more engaging and interactive experiences.

AR and VR are two technologies that are fast progressing and have revolutionized how we view and interact with the digital world [4]. Immersive experiences may be had with AR and VR, but the two technologies take quite different approaches and are used for other things [5]. While AR provides an improved version of the natural world by superimposing computer-generated content on top of it, VR generates an entirely synthetic setting. AR is a technology that enhances a user's view of their surroundings and their ability to interact with those surroundings by integrating digital information, such as photographs, videos, and three-dimensional models, into the user's actual environment. AR can be experienced through various devices, including smart glasses, headsets, smartphones, and tablets [6]. AR technology identifies the user's surroundings and superimposes virtual information on top of them in real time. It is accomplished using sensors and cameras. This technology has applications in a variety of domains, including gaming, education, healthcare, manufacturing, and marketing, to name a few.

Conversely, VR transports people into a simulated setting, entirely disconnecting them from the real world. VR often necessitates using a headset, which covers the user's eyes and ears and blocks extraneous inputs [7]. Users can engage with and travel around virtual places using VR, which generates a sensation of presence using high-resolution displays and motion-tracking technologies. VR can be used for various purposes, including but not limited to gaming and entertainment, as well as education, training, architecture, and treatment. AR and VR technologies are not incompatible, and they have a substantial crossover. The term "mixed reality" (MR) refers to the combination of components from both the actual and digital worlds in which digital items interact with the real-world setting [8]. The advantages of AR and VR are brought together in MR, which results in an experience that is both smoother and more interactive [9], [10]. The progress in computer vision, spatial mapping, and machine learning has allowed these fields to converge.

AR and VR each offer a variety of advantages. They could redefine entertainment while increasing productivity, upgrading learning experiences, developing more realistic simulations, and offering new learning opportunities [11]–[14]. AR can provide customers with up-to-date information and support, whereas VR can transfer them to new, engaging virtual worlds [15]. However, some obstacles need to be conquered, such as the requirement for technology that is both more compact and more affordably priced, the prevention of motion sickness while using virtual reality, the enhancement of user interfaces, and the protection of users' privacy and security when using augmented reality applications. The ongoing research and development are pushing the boundaries of what is possible, indicating that the future of AR and VR holds much promise. It is anticipated that the expansion of AR and VR reality will be fueled by hardware developments, such as lighter and more powerful headsets and the widespread use of 5G technology. The combination of artificial intelligence and machine learning will significantly expand the capabilities of both technologies. We may anticipate that AR and VR will become fundamental components of our day-to-day lives as they become more straightforward and widely available. It will cause a significant shift in how we carry out our jobs, connect, educate ourselves, and entertain ourselves.

The ASEAN area has emerged as a center for ground-breaking research and innovation in AR and VR. They have acquired tremendous traction recently, which has the potential to alter a variety of industries, ranging from the entertainment and gaming industries to educational institutions and healthcare facilities. In ASEAN, researchers, scientists, and businesspeople are capitalizing on the enormous potential offered by immersive technology to mound the future of digital experiences [16], [17].

Education is one of the most notable areas that has seen significant growth in ASEAN's AR and VR research. These technologies are progressively being included in the curricula of educational institutions around the region to create learning environments that are dynamic and interesting for their students. Students can better visualize complex topics, engage in interactive virtual simulations, and acquire real-world knowledge that cannot be obtained from reading standard textbooks using AR and VR technology [18]–[20].

In addition, augmented and virtual reality are currently playing crucial roles in changing the healthcare industry in ASEAN. These immersive technologies provide medical practitioners with the tools they need to better their skills and the results for their patients. Some examples of these technologies include surgical training simulators and virtual rehabilitation programs. AR and VR allow healthcare professionals to practice procedures and interventions in a risk-free setting by simulating actual scenarios, which they may recreate with the help of these technologies. The ASEAN region has also seen increased research and development in AR and VR within the gaming and entertainment sectors. Users can now immerse themselves in engaging virtual worlds because of the growing number of game developers and studios adopting these technologies. These worlds allow users to interact with lifelike characters, explore virtual landscapes, and participate in multiplayer activities.

ASEAN member states are promoting joint efforts to encourage research in augmented and virtual reality through various venues. One of these initiatives is the ASEAN Cyber University (ACU), an online learning network to strengthen regional collaboration in AR and VR research and development [21]. In addition, frequent events such as conferences, workshops, and contests centered on AR and VR are planned to encourage the sharing of information and possibilities for networking between researchers and

practitioners in the region. It is anticipated that the economy of the ASEAN region will continue to expand significantly, and substantial technical improvements will also occur as the area continues to invest in research and development related to augmented reality and virtual reality. Combining these immersive technologies with other developing sectors like artificial intelligence and the internet of things gives unlimited potential for producing creative solutions and revolutionizing industries across ASEAN.

Looking ahead, the future of AR and VR in ASEAN appears promising, with continued growth and innovation expected in the coming years. As technology continues to evolve and become more accessible, AR and VR are poised to become integral parts of daily life in ASEAN, offering new opportunities for businesses, educators, and consumers alike. This article explores the current landscape of AR and VR development in ASEAN and highlights the potential impact of these technologies on the region's economy and society. Besides that, it goes into AR and VR research in ASEAN to illuminate the significant breakthroughs, crucial projects, and ongoing collaborations influencing the region's technological landscape. The ASEAN countries are changing businesses, increasing user experiences, and altering how people interact with digital material by leveraging the power of AR and VR.

2. METHOD

2.1. Bibliometric analysis

The most recent version of the VOSviewer program, which was developed at Leiden University in Leiden, the Netherlands, was utilized so that bibliometric networks could be generated and visualized. With the use of this software, it is possible to glean information from previously published works, such as the author, magazine, organization, country, and keywords [22]. For the bibliometric study, version 1.6.17 of the VOSviewer program was utilized [23]–[27]. The figures and tables that were created were done so with the help of the data that was acquired. The following is a list of the bibliometric indicators that, according to the conclusions of some earlier bibliometric study, were the most important to this work and were addressed by it: i) the type of document, ii) the author, iii) the institution, iv) the country, v) the cited document, vi) the journal source, and vii) authors' keywords that commonly occur together in the same context [28]–[30]. The VOSviewer may generate a network of co-occurrence terms by importing exported Excel data and taking phrases from the index keyword into account. Finding the transdisciplinary techniques and choosing the appropriate research topics go hand in hand with the co-occurrence of phenomena [28], [29], [31]–[34]. The following programs were utilized to visualize the data: VOSviewer, Tableau Public, and Microsoft Excel.

The Scopus database was searched as part of the initial phase of the search, and the documents that were gathered for the study were analyzed in three stages as shown in Figure 1. The Scopus database is searched for records during phase 1, which is also known as the data collecting phase. The records that are found during this phase are then refined using the search parameters that were specified. Following that, the initial dataset contains some data that is identical to other data. To begin, a piece of software called OpenRefine was utilized in order to remove the redundant data from the system. Desktop software that is both open-source and free, this program is utilized for data cleansing and transformation, and it is available to anybody [35], [36]. In the second phase, also known as the "data visualization phase," the document is exported to the VOSviewer program so that bibliometric analysis may be performed on it about publications, authors, countries, institutions, and journals. The third phase will focus on determining which key issues were brought to light by the research on AR and VR in ASEAN.

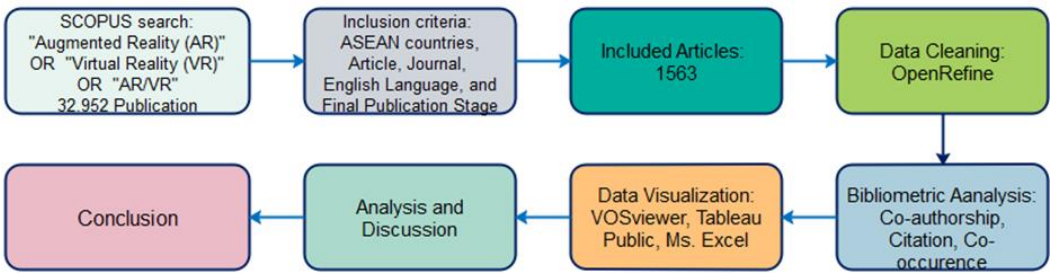

Figure 1. Flow chart bibliometric analysis process

The documents that were used in this investigation were mined from the Scopus database. This database is widely recognized as being suitable for bibliometric research due to the fact that it contains

content that has been published in indexed journals that cover a wide range of subject areas. This resource has had a substantial amount of utilization within the bibliometric analytic community [37]. Utilizing the campus network, which already gives access to Scopus, is how students, faculty, and staff at Universitas Negeri Yogyakarta can have access to the scholarly database known as Scopus.

2.2. Findings

According to the information in Table 1, the final document that was retrieved following the filtering process was given the number 1,563. The data is exported in the form of a "CSV" file, which includes all notes and references that were cited. A network map that includes authors, countries, and keywords will be developed as a direct result of the data. In addition to that, according to the findings of the research that was conducted on citations, as well as the findings of a network map of the journal that was created because of the investigation. In order to facilitate a more transparent comprehension of how the bibliometric data are related to one another, the findings are presented in the shape of interlocking rings [38].

Table 1. Publication percentage in each region

No	Country	Number of documents	Percentage
1	USA	6,388	19.39%
2	China	3,140	9.53%
3	United Kingdom	2,040	6.19%
4	European Union	9,083	27.56%
5	East Asia	4,603	13.97%
6	Latin America	741	2.25%
7	Australian and New Zealand	1,556	4.72%
8	South Asia	795	2.41%
9	Middle East	1,120	3.40%
10	Africa	151	0.4%
11	ASEAN	1,563	4.74%

Figure 1 shows that the number of publications in the ASEAN region is still quite tiny, accounting for only 4.74% of all publications worldwide. With these statistics, there are still many potentials for ASEAN researchers to expand their research on this area. Figure 2 depicts the number of publications on the same topic in other locations. It will be noticeable in the percentage of publications in ASEAN and other regions. When compared to Africa, South Asia, the Middle East, Australia and New Zealand, and Latin America, ASEAN shines.

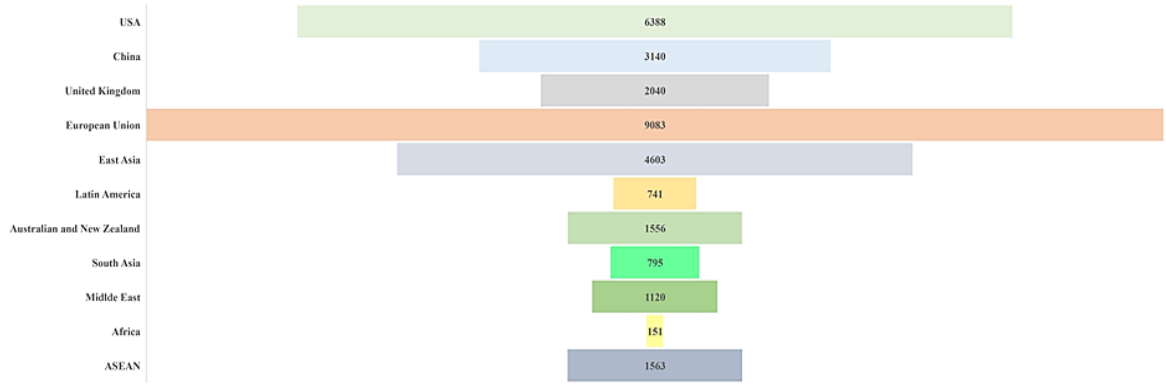

Figure 2. Data comparison with others region in the world

Table 1 demonstrates the dominance of countries with great technological capacity in this sector of research. The European Union has the highest rate of 27.56%, followed by the United States and East Asia with 19.39% and 13.97%, respectively. This data can be utilized as a parameter for other regions to generate research topics in the field of AR and VR, allowing them to compete with developed countries in this field.

The amount of space that is left between two or more circles can be interpreted as a representation of the degree to which the ideas that are represented by each circle are related to one another. The many distinct types of phrases are differentiated from one another by using different colors. In addition to this, the size of

the circle is exactly proportional to the total number of occurrences of the term in the data [39]–[41]. It is possible that the number of clusters displayed on each network map will differ based on the links. To avoid confusion caused by multiple interpretations of the same word, the labels are frequently not printed alongside the words. It should also be mentioned that the "thesaurus" function included in VOSviewer is being utilized to selectively omit terms that are either unnecessary or inappropriate for this investigation. In addition, the study analyses the linkages between the words that make up each cluster and the debate of controversial subjects by looking at how the two are related. The full process can be explained in Tables 2 and 3. Table 2 show the initialization stage and Table 3 show the filter stage result.

Table 2. Initialization stage result

Initialization stage result	
Search time	May 30, 2023
Search documents	TITLE-ABS-KEY ("*Augmented Reality (AR)" OR "Virtual Reality (VR)" OR "AR/VR")*
Year	1994 - 2023
Documents type	All
Results obtained	32,952

Table 3. Filter stage result

Filter stage result	
Country	*Malaysia, Indonesia, Singapore, Thailand, Viet Nam, Philippines, Brunei Darussalam, Myanmar, Cambodia, Laos.*
Document type	*Conference paper, Article*
Source type	*Proceedings, Journal*
Language	English
Pub stage	Final
Results obtained	1563

A search conducted on the Scopus database using keywords connected to AR and VR research in ASEAN countries between the years 1994 and 2023 produced a total of 1,563 publications (proceedings and journals). As shown in Figure 1, the category of publication known as proceedings is the one that receives the most citations overall. It accounts for 52% of all citations. Articles published in journals make up 48% of the total. Articles created during this period account for the vast majority (by far the majority) of all other forms of publishing that took place during this time period.

The findings, which are depicted in Figure 1, indicate that the overall number of articles has a growing pattern. Figure 3 shows that the total number of published articles increased steadily between the years 2000 and 2008, reaching even higher levels between 2009 and 2022. Publications that are presented at conferences are in great demand for a variety of reasons, including those that are listed below: i) a conference paper has a more extraordinary reputation; ii) having it on exhibit at a conference where specialists from a wide variety of professions will be able to see it increases both its impact and its accessibility; iii) the quality of the paper received is high because not all scientific writings can be accepted at the conference; and iv) conferences are held more frequently while journals take a more extended amount of time to publish at the meeting, publications.

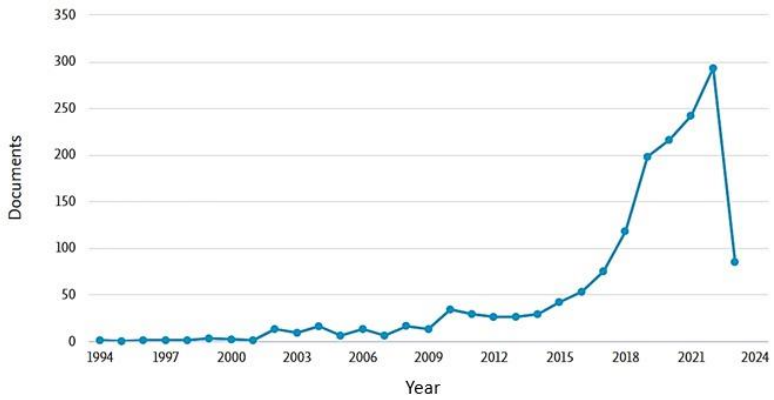

Figure 3. Documents per year (proceedings and journals)

3. RESULTS AND DISCUSSION

3.1. Co-authorship analysis

The interaction that takes place in a social setting between two or more scientists to promote the sharing of meaning and the completion of tasks in relation to a mutually shared aim can be referred to as scientific collaboration. This type of interaction can be characterized as the type of interaction that takes place. Scientists are motivated to collaborate due to the possibility of uncovering new information, the growing specialization that exists within the scientific community, the complexity of the infrastructure that is necessary, and the requirement to combine various types of knowledge and abilities to handle complicated health issues. Because it gives researchers access to information from a wider range of fields, scientific collaboration can also serve to increase the breadth of an ongoing research endeavor and stimulate innovative thinking. Nodes in co-authorship networks can represent authors, organizations, or nations, and they are connected to one another whenever the respective authors of a publication also belong to the same co-authorship group [42], [43].

The data from the author analysis show that there are 4,463 writers who have authored works on augmented reality and virtual reality and made their work available to the public. 105 authors have at least five papers tied to their identities across the various platforms. There are a total of fifteen authors who are among the most productive, as indicated by the number of documents displayed in Figure 4. Ong S.K. is the author with the most publications, with 58, followed by Nee A.Y.C with 56 documents and Ismail A.W., who has 29.

Research impact can be quantified partly by the frequency with which a study is cited. It makes it possible to investigate books, journals, and academic establishments more deeply. As can be seen in Figure 5, Ong S.K. (2909) has been referenced more times than any other individual. It was found that Nee A.Y.C. had a total of 2,893 works, Yuan M.L. had 459 citations, Wang X had 431 results, and Cheok A.D. had 394 citations. Each of these publications has acquired many citations, proving that researchers are still interested in the subject matter presented.

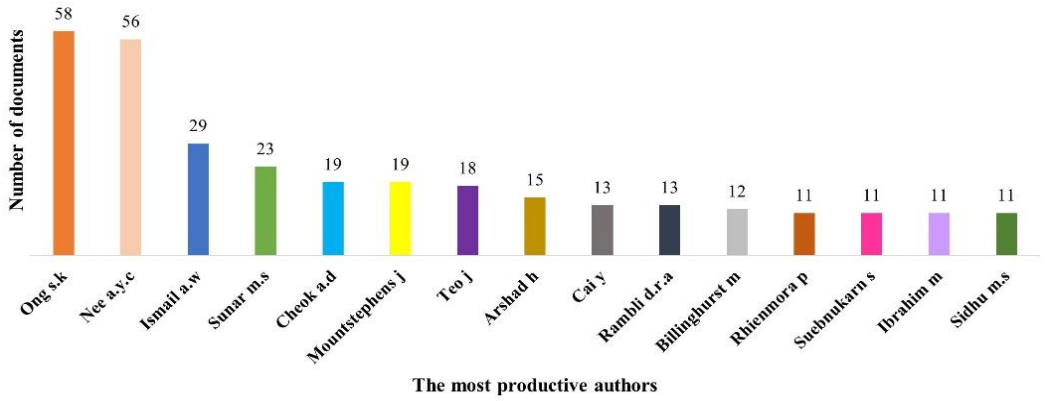

Figure 4. Top author documents

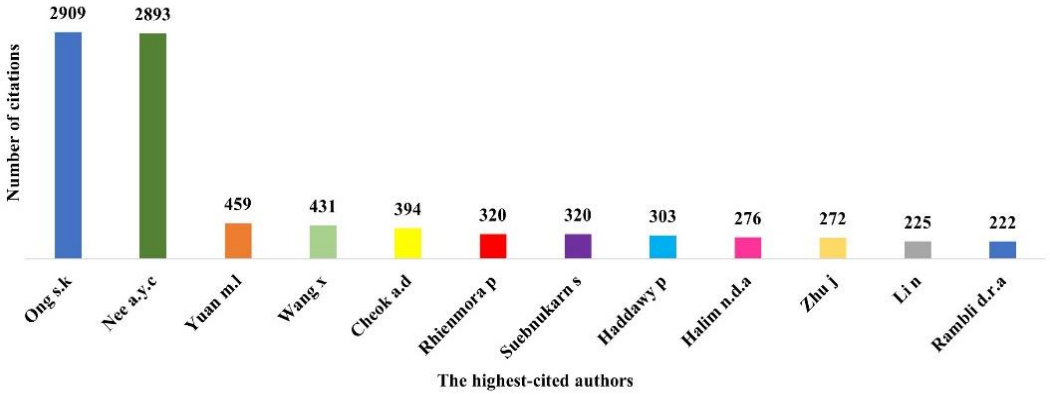

Figure 5. Top 10 citations

The total link strength characteristic indicates the overall strength of the co-authorship relationships that connect a specific researcher to other researchers. In addition to the default links and total link strength properties, things may also have particular weight attributes. Ong S.K. has the highest total link strength, 112, as seen in Figure 6. It means they are connected to most other researchers thanks to their contributions. With 109 fewer members, Nee A.Y.C. comes in second. Conclusions like these points have the opportunity for future chances to collaborate with these authors on computational thinking projects. These results show that the total number of citations and the total strength of linkages are not always proportional to the large number of papers.

The tree map of the leading institutions in ASEAN countries with the most documents on AR and VR is displayed in Figure 7. This investigation was successful in identifying 3,027 research institutions or universities that are engaged in the study of augmented reality and virtual reality (AR/VR). Fourteen groups in this area have each published five or more documents collectively. The Mechanical Engineering Department of the National University of Singapore has the most documents of any organization in Singapore, with 33 papers. In addition to that, the School of Computer Science and Engineering at Nanyang Technological University in Singapore has produced 12 documents. The School of Computing at the Faculty of Engineering at Universiti Teknologi Malaysia has produced seven papers, which places it in second place after the National University of Singapore, which has produced 11 documents.

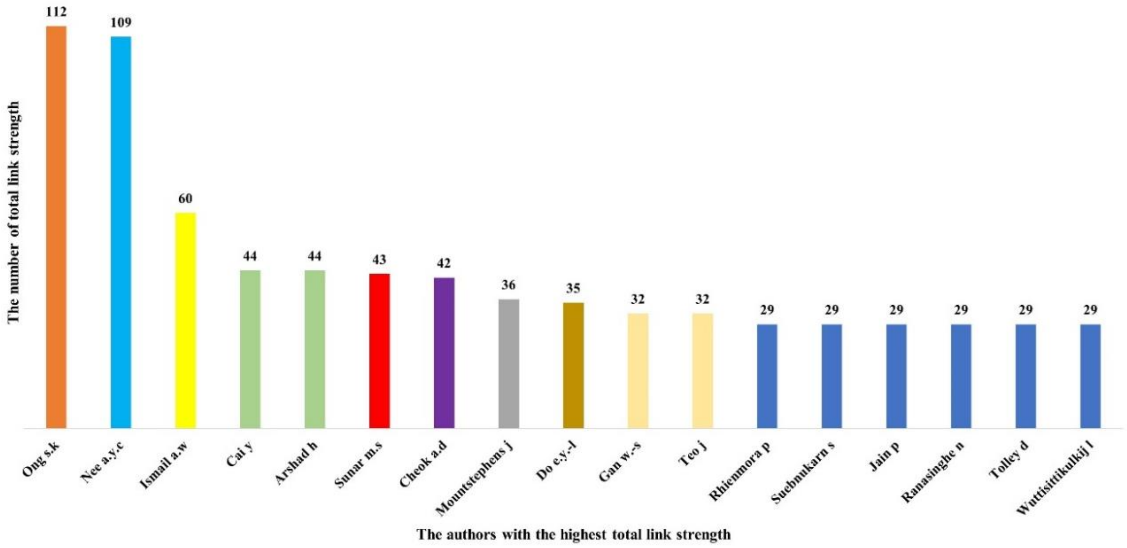

Figure 6. Top 10 total ling strength author

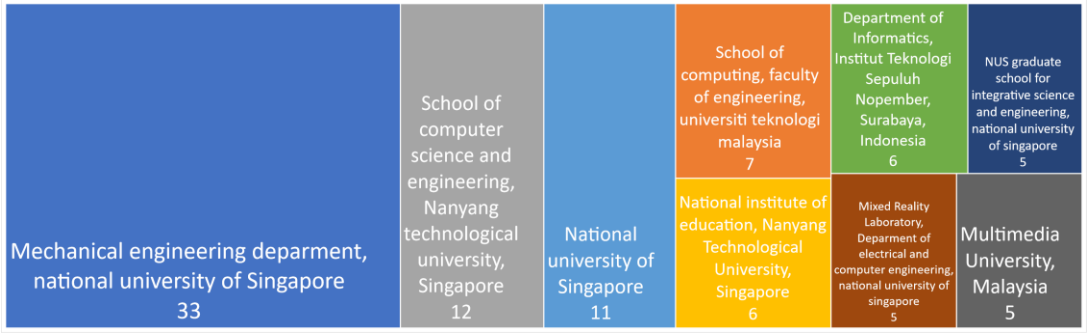

Figure 7. Top organization

Regarding citations, the Mechanical Engineering Department of the National University of Singapore is tied first with 1,156 citations. Next comes the School of Computer Science and Engineering, Nanyang Technological University, Singapore, which has four documents cited by 180 sources, making it the

second most-cited institution. Last is the NUS Graduate School for Integrative Science and Engineering, the National University of Singapore, which has 165 citations. Based on these numbers, there is much room for improvement in AR/VR research collaboration in academic institutions between ASEAN countries.

In Figure 8, we see the semantic document network spread out over the world. The topic of augmented reality and virtual reality research in ASEAN is led by Malaysia, which has 587 publications and total link strength of 46. Indonesia came in second, with 407 papers and 43 overall link strengths. Afterwards comes Singapore, with a total of 365 publications and link strength of 4. Academic study of AR/VR has grown rapidly and become increasingly important in many different regions. The global link strength figure reveals that nations like Thailand, Philippines, Vietnam, Brunei Darussalam, Myanmar, Cambodia, and Laos produce an outsized number of the world's articles. Technology also plays a crucial role in the development of AR/VR study. Because of this, knowing your way around technology is crucial. This is a great opportunity for countries that have not previously published in the field of AR/VR to collaborate and establish research networks. In Figure 9, we see a more comprehensive graphic representation of the countries that have made major contributions to this field of study. In the first and second bars, respectively, graphs of each country's production in AR/VR as well as the number of papers created by that country, its position within the field, and the citations are displayed.

According to Table 4, publications written by Nee *et al.* [44] describe how augmented reality is used in the design and manufacturing processes. When compared to other kinds of applications, this one is still in its early stages of development. Primarily because of the high level of accuracy that is necessary while utilizing the program in terms of tracking and registration. In addition to this, it also refers to the fact that it is compatible with the procedures that are typically used. This application places a strong emphasis on ergonomics, human factors, and cognitive aspects as well. This is since; unlike users who are playing augmented reality games, which can be stopped at any time, engineering users typically spend a significant amount of time utilizing the system for their work in addition to serving services. In this study, AR applications that are applicable to the manufacturing industry are given, even if most of these applications are still in the early stages of development in the laboratory. This article places a strong emphasis on the importance of the design stage, as well as the provision of an effective and user-friendly human interface, as well as the creation of appropriate content, to make AR a valuable tool in production engineering. It has also been speculated how AR may evolve in the future so that it can incorporate real-world examples into its development.

The second most-cited article is one that is written by Lee *et al.* [45] regarding the potential for VR to improve learning outcomes. In this study, the contribution of desktop VR-based learning is assessed to determine the basic theoretical model that will be used to get the components that influence the efficiency of learning. By methodically and experimentally testing the adjustment of the desktop VR-based learning environment with the theory of the created model, the theoretical framework has been determined in a constructive manner. This has allowed for the testing of the adjustment to take place. The creation of this framework was done with the goal of making it simpler to develop it in the years to come. In addition to this, the framework offers practitioners and academics insight as well as an in-depth grasp of how to build it in learning.

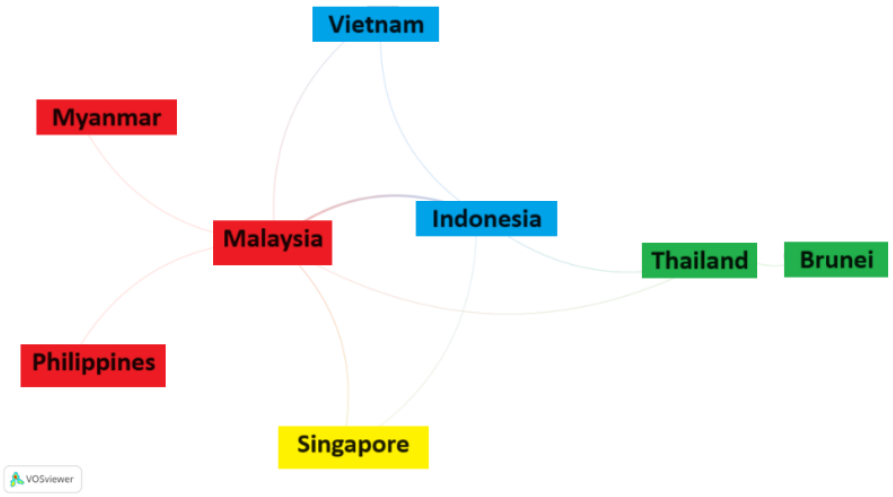

Figure 8. Network between ASEAN countries

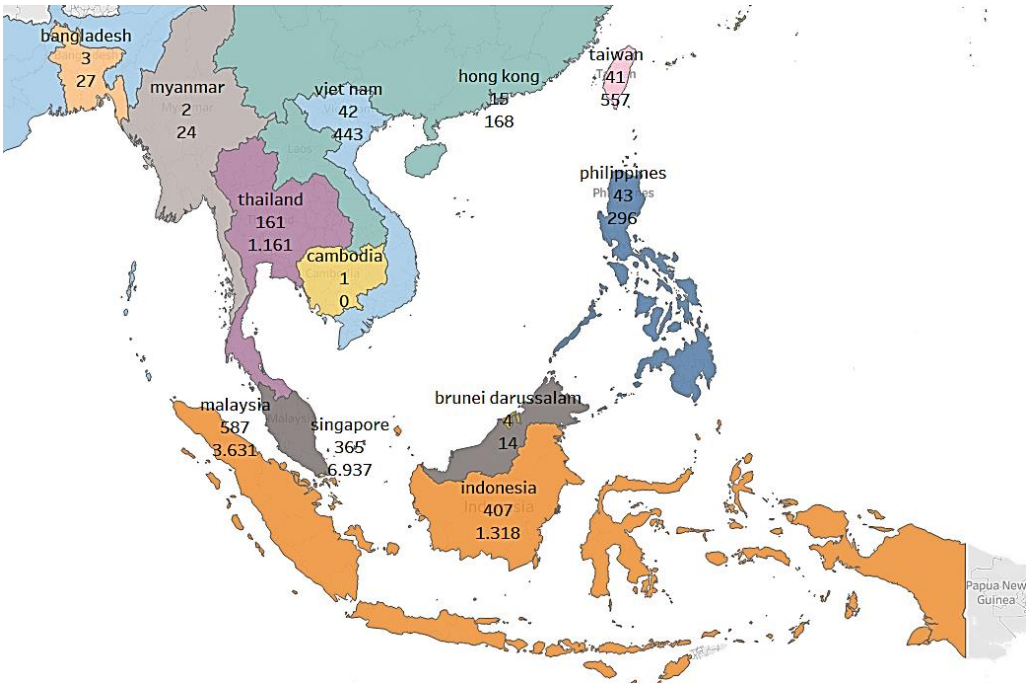

Figure 9. Visualization of the top AR/VR research countries

Table 4. Top 10 articles with the highest citations

No	Authors	Findings	Cited	Ref
1	Nee *et al.* 2012	Most AR applications for manufacturing are still in the lab, but this study covers some. AR may be a significant tool in production engineering if it has intuitive and effective human interfaces and appropriate content development, according to the paper.	531	[44]
2	Lee *et al.* 2010	This study presents a theoretical model of desktop VR-based learning effectiveness determinants. We established a broad framework to identify theoretical elements and their relationships in a desktop VR-based learning environment and empirically validated the theoretical model's fit. A framework and paradigm will drive desktop VR-based learning environment development.	315	[45]
3	Wang *et al.* 2015	An analysis of cutting-edge AR technology, including tracking and registration issues, collaborative AR interface, 3D workspace scene capture, knowledge representation and context awareness, is used to discuss current AR assembly system bottlenecks and potential future work directions. Readers may rapidly uncover study areas where AR can improve assembly systems by analyzing cutting-edge AR technology development.	300	[46]
4	Ong *et al.* 2008	AR uses in manufacturing and other industries are experimental. AR technology can aid many manufacturing procedures with better tracking and registration algorithms and faster hardware response time.	255	[47]
5	Lin *et al.* 2013	The learners who utilized the AR Physics system demonstrated significantly superior learning outcomes compared to those who utilized the traditional 2D simulation system in relation to the subject of elastic collision.	204	[48]
6	Saidin *et al.* 2015	AR features can enrich students' learning and visualization skills. Teachers can use AR technology to explain and help pupils understand. Participants and students interested in using AR in learning have also given excellent feedback.	141	[49]
7	Park *et al.* 2019	We further investigate the imaging capabilities of our meta lens by employing a color-pixel sCMOS camera and scanning-imaging techniques. This allows us to showcase possible applications in virtual reality (VR) devices and biological imaging approaches.	138	[50]
8	Li *et al.* 2003	The virtual environment for different maintenance tasks can be readily created by customizing 3D models to STL format. The author is unaware of a desktop VR system for maintenance instruction. This means the maintenance training system is portable and cheap.	138	[51]
9	Chong *et al.* 2009	This paper proposes an AR-based robot programming method. This work proposes a scalable RPAP approach for in situ robot programming, providing flexibility and adaptability to varied situations. The RPAP method lets a user directly control a scaled virtual robot in a natural environment to follow their operating courses.	123	[52]
10	Santos *et al.* 2016	AR can improve learning by reducing cognitive load, enhancing attention, and increasing satisfaction, not just post-tests. Our initial trials imply that AR as multimedia may improve attention and satisfaction.	121	[53]

3.2. Co-occurrence analysis

Co-occurrence analysis is a method that is used in text or data analysis to discover and study the relationship between two or more items or components that appear together in a context or document. The purpose of this analysis is to better understand how these items or elements are related to one another. It is possible to recognize patterns and connections between these components by utilizing this strategy. Co-occurrence analysis is carried out in the context of a text by paying attention to the ways in which certain words or phrases appear many times inside the same text. This approach can be helpful in comprehending the setting, establishing the connection between individual words, and gleaning information from the written content. Analysis of co-occurrences has applications in a variety of other domains, including social data analysis, network analysis, and picture analysis, to name a few. The primary objective of co-occurrence analysis in any given setting is to uncover latent links and patterns between components that show up together in a specific data set or setting. This is the case regardless of the setting.

According to the results presented in Figure 10, the co-occurrence analysis performed with the author keywords resulted in the discovery of five distinct groups of keywords. These groups developed network visualizations among phrases obtained from AR/VR subjects. The groupings that were produced as a result characterize different avenues of inquiry based in AR/VR. These topics are undergoing certain shifts, and as a result, new terms that are more specific to each subfield are coming to the fore. Details of the keyword clustering can be seen in Table 5.

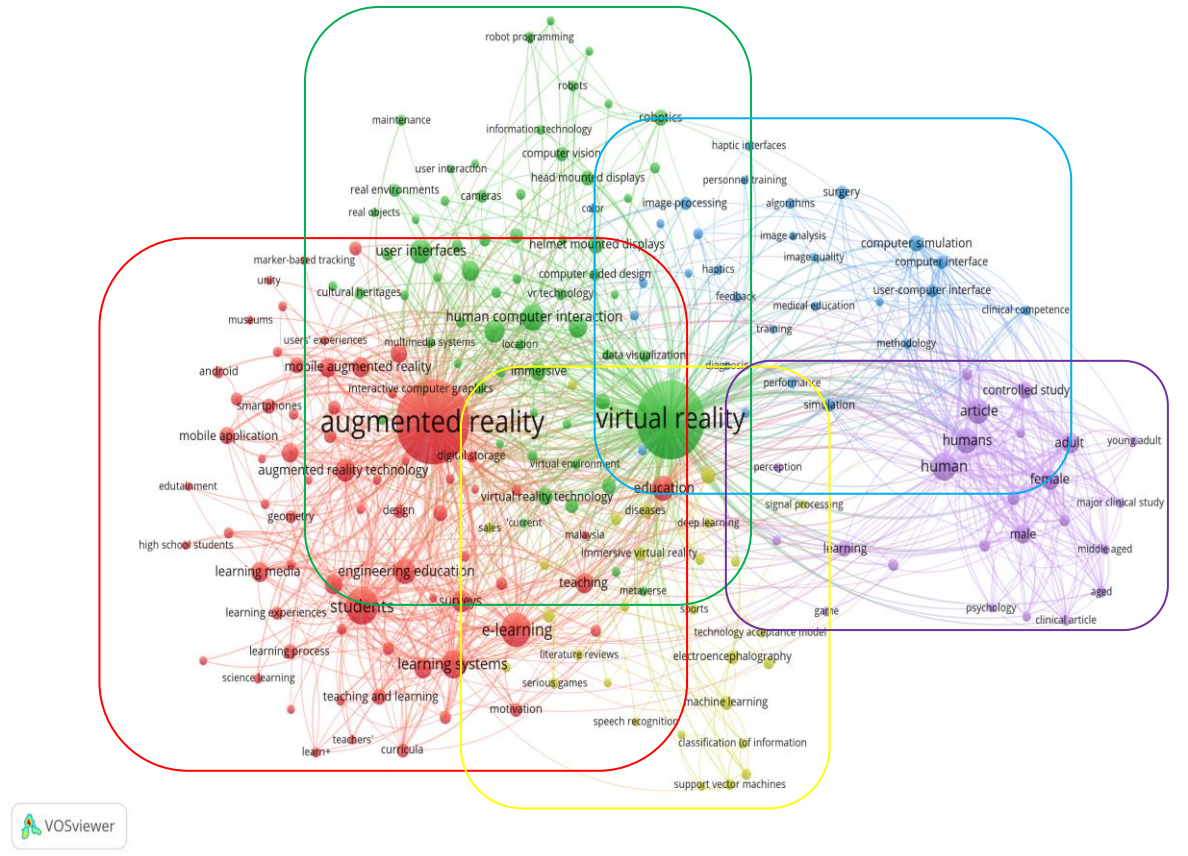

Figure 10. Keywords visualization in several cluster in the AR/VR research topics

As demonstrated in Figure 11, the concept of network visualization can be viewed as an example of an overlay visualization. It does this by superimposing a graphical representation of the trend in the number of studies that have used these phrases over the course of the specified bibliometric analysis period's most recent five years. The yellowish nodes (2020-present) represent the direction or popularity of newer research that many other academics have not done, whilst the blue nodes (2014-2018) reflect regularly or often used terms. This research was not done by a lot of other researchers.

Table 5. Frequent occurrence keywords in each cluster

Cluster	Frequent occurrence keywords
1 (Red)	augmented reality; e-learning; students; learning system; education; engineering education; learning media; education computing; teaching; teaching and learning; augmented reality technology; mobile applications; mobile augmented reality; 3D modelling; user experience; surveys; learning environment; curricula.
2 (Green)	virtual reality; virtual objects; human computer interaction; user interfaces; virtual reality technology; three-dimensional computer graphics; internet of things; visualization; architectural design; immersive; robotics; data visualization; cultural heritage, computer aided design.
3 (Purple)	human; humans; article; female; adult; male; learning; controlled study; procedures; randomized controlled trial; young adult; physiology; human experiment.
4 (Yellow)	artificial intelligence; deep learning; immersive virtual reality; technology acceptance model; electroencephalography; serious games; motion sickness; eye tracking; speech recognition; gamification
5 (Blue)	computer simulation; computer interface; surgery; clinical competence; performance; algorithms; methodology.

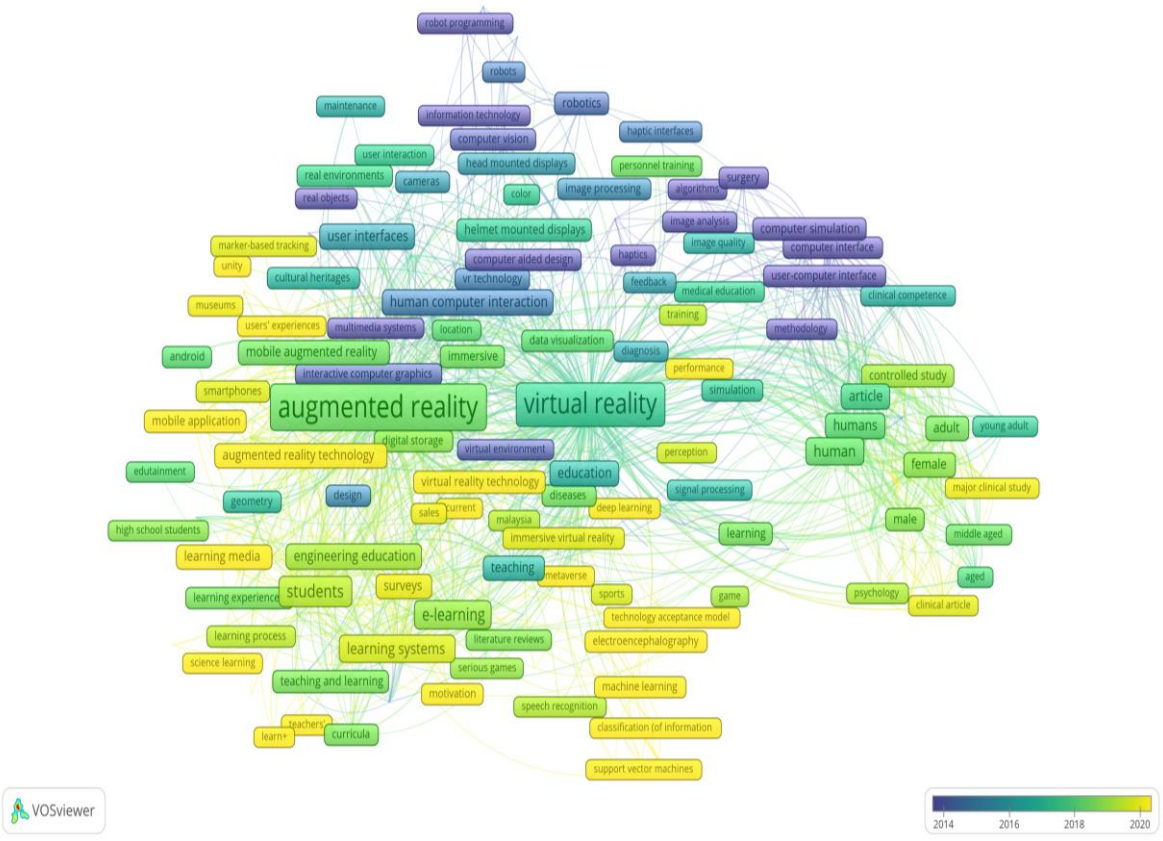

Figure 11. Overlay visualization for keywords in AR/VR topics

3.3. Limitations

The study of AR and VR is an intriguing endeavor that is undergoing rapid development; nevertheless, it is not without its fair share of constraints. The limitations imposed by technology are one of the most severe restrictions. The AR and VR technologies are making steady strides forward, but there are still a number of technological obstacles that researchers must overcome. The user experience can be impacted, as well as the results of research, when problems like as a restricted field of view, poor resolution, pain, or latency are present. In addition, the high costs involved in designing and maintaining AR/VR systems might limit access and inhibit widespread acceptance. This makes it difficult to perform studies on a large scale or generalize findings across a variety of demographics. In addition, there is a lack of standardized research procedures and measures, which is another restriction. Because the AR/VR research field is still relatively new, there is not yet a well-established set of best practices or evaluation frameworks that are generally recognized. Because of this, it is difficult to compare studies or reproduce experiments, which slows down the overall progression of the field. In addition, because applications for augmented and virtual

reality can be found in a variety of fields, such as gaming, healthcare, education, and others, it can be challenging to create consistent research protocols and outcome measures that are tailored to a particular environment or application. These restrictions underscore the necessity for on-going research and development in AR/VR in order to overcome technical constraints, establish standardized techniques, and address the issues connected with cost and accessibility. Researchers can develop the area and unlock the full potential of augmented and virtual reality technology for a variety of sectors and domains if they solve the constraints that have been identified.

While the bibliometric study provides valuable insights into the quantitative aspects of AR/VR research in ASEAN, future research could delve deeper into the qualitative aspects. This could involve conducting interviews or surveys with researchers and practitioners in the field to understand the motivations, challenges, and future directions of AR/VR research in the region. A comparative analysis of AR/VR research trends in ASEAN with global trends could provide valuable insights. This could help identify areas where ASEAN countries are leading or lagging behind in AR/VR research and development, and facilitate knowledge exchange and collaboration with other regions. AR/VR technologies are rapidly evolving, and new applications are constantly emerging. Future research could focus on identifying and analyzing the emerging applications of AR/VR in ASEAN, particularly in industries such as education, healthcare, tourism, and manufacturing. AR/VR technologies are not only driven by technological advancements but are also influenced by regulatory and policy frameworks. Future research could examine the policy implications of AR/VR development in ASEAN, including intellectual property rights, data privacy, and ethical considerations. Collaboration among researchers, industry stakeholders, and policymakers is crucial for fostering innovation in AR/VR technologies. Future research could explore strategies for promoting collaboration and knowledge sharing in the ASEAN region to accelerate the development and adoption of AR/VR technologies. As AR/VR technologies become more pervasive, it is important to consider their ethical and social implications. It will explore the ethical issues related to the use of AR/VR technologies in ASEAN, such as privacy, security, and inclusivity, and propose guidelines for ethical AR/VR development and deployment.

4. CONCLUSION

AR/VR subject matters are required for effectively summarizing, explaining, and conveying the most important findings and implications of research carried out in these disciplines. These conclusions typically provide valuable insights into the efficacy, usability, and impact of augmented reality and virtual reality technology. In the field of research, it is usual practice to arrive at findings based on the researchers' own empirical data, analyses, and interpretations of the results. The potential for augmented and virtual reality technologies to improve a wide variety of disciplines and provide better user experiences is a popular topic in discussions about these technologies. Research has demonstrated that augmented and virtual reality (AR/VR) can have a beneficial impact on learning outcomes, the acquisition of skills, and the overall effectiveness of training. For instance, studies conducted in educational settings have shown that students' engagement levels, the amount of information they are able to remember, and their ability to solve problems can all be improved by using immersive virtual environments. In a similar vein, applications of augmented and virtual reality (AR/VR) have demonstrated considerable potential in the medical field, particularly in the areas of pain management, rehabilitation, and surgical training. These research findings emphasize the transformational potential of AR and VR technologies and show their promise to revolutionize how we learn, work, and interact in various disciplines.

AR and VR discussions frequently center on the question of whether or not users will accept newly developed technologies and how practical they will be. Studies have been conducted to investigate the elements that influence user pleasure, comfort, and engagement with augmented reality and virtual reality experiences. According to research done, user acceptability and enjoyment are highly impacted by aspects such as how simple the interface is to use, how realistic the environment is, how interactive the experience is, and how high the quality of the content is. It is essential to get an understanding of these facets in order to ensure the long-term viability of augmented and virtual reality technologies and ensure their effective adoption. The findings in this domain enable researchers and developers establish design principles, standards, and best practices to create immersive and user-friendly experiences that cater to the needs and preferences of people.

In conclusion, themes related to augmented and virtual reality (AR/VR) provide helpful insights into the potential benefits that could be derived from these technologies and shed light on the elements that influence the factors that influence user acceptability and engagement. These findings contribute to the expanding body of knowledge in the field and will influence future research, development, and deployment of AR/VR technologies across a variety of sectors and domains.

REFERENCES

[1] ASEAN Secretariat, *ASEAN Digital Masterplan 2025*. ASEAN Publication, 2024.

[2] H. L. C. Julian, T. Chung, and Y. Wang, "Adoption of Metaverse in South East Asia: Vietnam, Indonesia, Malaysia," in *Strategies and Opportunities for Technology in the Metaverse World*, IGI Global, 2023, pp. 196–234.

[3] I. Yaqoob, K. Salah, R. Jayaraman, and M. Omar, "Metaverse applications in smart cities: enabling technologies, opportunities, challenges, and future directions," *Internet of Things*, 2023.

[4] N. Elmqaddem, "Augmented reality and virtual reality in education. Myth or reality?," *International journal of emerging technologies in learning*, vol. 14, no. 3, 2019.

[5] X. yue Qiu, C. K. Chiu, L. L. Zhao, C. F. Sun, and S. jie Chen, "Trends in VR/AR technology-supporting language learning from 2008 to 2019: a research perspective," *Interactive Learning Environments*, pp. 1–24, 2021, doi: 10.1080/10494820.2021.1874999.

[6] F. Arici, P. Yildirim, Ş. Caliklar, and R. M. Yilmaz, "Research trends in the use of augmented reality in science education: content and bibliometric mapping analysis," *Computers and Education*, vol. 142, 2019, doi: 10.1016/j.compedu.2019.103647.

[7] E. M. Bourhim and A. Cherkaoui, "Efficacy of virtual reality for studying people's pre-evacuation behavior under fire," *International Journal of Human Computer Studies*, vol. 142, 2020, doi: 10.1016/j.ijhcs.2020.102484.

[8] K. J. L. Nevelsteen, "Virtual world, defined from a technological perspective and applied to video games, mixed reality, and the Metaverse," *Computer Animation and Virtual Worlds*, vol. 29, no. 1, pp. 1–36, 2018, doi: 10.1002/cav.1752.

[9] R.-A. C\ualin, "Virtual reality, augmented reality and mixed reality-trends in pedagogy," *Social Sciences and Education Research Review*, vol. 5, no. 1, pp. 169–179, 2018.

[10] H. R. Malik, N. A. Nawaz, and M. B. Al-Zghoul, "Impact of augmented reality and virtual reality in the transformation of virtual customer relationship management sector," in *2020 IEEE 7th International Conference on Engineering Technologies and Applied Sciences (ICETAS)*, 2020, pp. 1–5.

[11] A. Christopoulos, M. Conrad, and M. Shukla, "Increasing student engagement through virtual interactions: How?," *Virtual Reality*, vol. 22, no. 4, pp. 353–369, 2018, doi: 10.1007/s10055-017-0330-3.

[12] M. Okechukwu and F. Udoka, "Understanding virtual reality technology: advances and applications," *Advances in Computer Science and Engineering*, 2011, doi: 10.5772/15529.

[13] T. N. Fitria, "Augmented reality (AR) and virtual reality (VR) technology in education: media of teaching and learning: a review," *International Journal of Computer and Information System (IJCIS)*, vol. 4, no. 1, pp. 14–25, 2023.

[14] J. M. D. Delgado, L. Oyedele, P. Demian, and T. Beach, "A research agenda for augmented and virtual reality in architecture, engineering and construction," *Advanced Engineering Informatics*, vol. 45, 2020.

[15] J.-Y. Zeng, Y. Xing, and C.-H. Jin, "The impact of VR/AR-Based consumers' brand experience on consumer--brand relationships," *Sustainability*, vol. 15, no. 9, 2023.

[16] D. K. Baroroh and A. Agarwal, "Immersive technologies in Indonesia faces" new normal" COVID-19," *International Journal of Technology*, vol. 13, no. 3, pp. 633–642, 2022.

[17] G. Trends, "2040: A more contested world," *The National Intelligence Council*, 2021.

[18] X. Zhao, Y. Ren, and K. S. L. Cheah, "Leading virtual reality (VR) and augmented reality (AR) in education: bibliometric and content analysis from the web of science (2018--2022)," *SAGE Open*, vol. 13, no. 3, 2023.

[19] A. A. Abd El-Latif, Y. Maleh, M. A. El-Affendi, and S. Ahmad, *Cybersecurity Management in Education Technologies: Risks and Countermeasures for Advancements in E-learning*. CRC Press, 2023.

[20] C. S. Ironsi, "Investigating the use of virtual reality to improve speaking skills: insights from students and teachers," *Smart Learning Environments*, vol. 10, no. 1, 2023.

[21] ACU Project, "Memorandum of understanding on the ASEAN cyber University project," ASEAN Cyber University Project, 2012.

[22] N. J. van Eck and L. Waltman, "Software survey: VOSviewer, a computer program for bibliometric mapping," *Scientometrics*, vol. 84, no. 2, pp. 523–538, Aug. 2010, doi: 10.1007/s11192-009-0146-3.

[23] Y. Qin, Z. Xu, X. Wang, and M. Škare, "Green energy adoption and its determinants: a bibliometric analysis," *Renewable and Sustainable Energy Reviews*, vol. 153, 2022.

[24] U. A. Muhammad *et al.*, "Bibliometric analysis of local wisdom-based learning: direction for future history education research," *International Journal of Evaluation and Research in Education*, vol. 11, no. 4, pp. 2209–2222, 2022, doi: 10.11591/ijere.v11i4.23547.

[25] N. A. Masduki, M. Mahfar, and A. A. Senin, "A bibliometric analysis of the graduate employability research trends," *International Journal of Evaluation and Research in Education*, vol. 11, no. 1, pp. 172–181, 2022.

[26] Y. D. Ariyani, I. Wilujeng, and S. I. A. Dwiningrum, "Bibliometric analysis of SCAMPER strategy over the past 20 years," *International Journal of Evaluation and Research in Education*, vol. 11, no. 4, pp. 1930–1938, 2022, doi: 10.11591/ijere.v11i4.22316.

[27] N. Suprapto *et al.*, "Research trend on TPACK through bibliometric analysis (2015-2019)," *International Journal of Evaluation and Research in Education*, vol. 10, no. 4, pp. 1375–1385, 2021, doi: 10.11591/IJERE.V10I4.22062.

[28] A. Christ-Ribeiro, L. M. Chiattoni, C. R. F. Mafaldo, E. Badiale-Furlong, and L. A. de Souza-Soares, "Fermented rice-bran by Saccharomyces cerevisiae: Nutritious ingredient in the formulation of gluten-free cookies," *Food Bioscience*, vol. 40, 2021, doi: 10.1016/j.fbio.2020.100859.

[29] S. H. Zyoud and A. H. Zyoud, "Visualization and mapping of knowledge and science landscapes in expert systems with applications journal: a 30 years' bibliometric analysis," *Sage Open*, vol. 11, no. 2, 2021.

[30] A. Rodríguez-Rojas, D. Y. Baeder, P. Johnston, R. R. Regoes, and J. Rolff, "Bacteria primed by antimicrobial peptides develop tolerance and persist," *PLoS Pathogens*, vol. 17, no. 3, pp. 1–30, 2021, doi: 10.1371/JOURNAL.PPAT.1009443.

[31] Y. Guo, Z. Huang, J. Guo, H. Li, X. Guo, and M. J. Nkeli, "Bibliometric analysis on smart cities research," *Sustainability*, vol. 11, no. 13, Art. no. 3606, 2019, doi: 10.3390/su111336062019.

[32] A. Lulewicz-Sas, "Corporate social responsibility in the light of management science - bibliometric analysis," *Procedia Engineering*, vol. 182, pp. 412–417, 2017, doi: 10.1016/j.proeng.2017.03.124.

[33] Gall, Gall, and Borg, "Situated ethics in educational research society for educational studies," *British Journal of Educational Studies*, vol. 49, no. 3, pp. 362–365, 2007.

[34] H. Nassaji, "Qualitative and descriptive research: data type versus data analysis," *Language teaching research*, vol. 19, no. 2. Sage Publications Sage UK: London, England, pp. 129–132, 2015.

[35] A. Groves, "Beyond Excel: how to start cleaning data with OpenRefine," *Multimedia Information and Technology*, vol. 42, no. 2, pp. 18–22, 2016.

[36] R. K. Tillman, "The Code4Lib journal – extracting, augmenting, and updating metadata in fedora 3 and 4 using a local openrefine reconciliation service," *Code4Lib Journal*, no. 31, pp. 1–12, 2016.
[37] E. Méndez, C. Ribeiro, G. David, J. C. Lopes, and F. Crestani, "Digital libraries for open knowledge," *22nd International Conference on Theory and Practice of Digital Libraries*, TPDL 2018, pp. 3–15, 2018, doi: 10.1007/978-3-030-00066-0.
[38] L. Skaf, E. Buonocore, S. Dumontet, R. Capone, and P. P. Franzese, "Applying network analysis to explore the global scientific literature on food security," *Ecological Informatics*, vol. 56, 2020, doi: 10.1016/j.ecoinf.2020.101062.
[39] A. Perianes-Rodriguez, L. Waltman, and N. J. van Eck, "Constructing bibliometric networks: a comparison between full and fractional counting," *Journal of Informetrics*, vol. 10, no. 4, pp. 1178–1195, 2016, doi: 10.1016/j.joi.2016.10.006.
[40] L. Waltman and N. J. van Eck, "Field-normalized citation impact indicators and the choice of an appropriate counting method," *Journal of Informetrics*, vol. 9, no. 4, pp. 872–894, 2015, doi: 10.1016/j.joi.2015.08.001.
[41] L. Waltman, "A review of the literature on citation impact indicators," *Journal of Informetrics*, vol. 10, no. 2, pp. 365–391, 2016, doi: 10.1016/j.joi.2016.02.007.
[42] J. Bezerra *et al.*, "A worldwide bibliometric and network analysis of work-based learning research," *Higher Education, Skills and Work-based Learning*, vol. 11, no. 3, pp. 601–615, 2020, doi: 10.1108/HESWBL-03-2020-0035.
[43] E. Fonseca *et al.*, "The nanograv nine-year data set: mass and geometric measurements of binary millisecond pulsars," *The Astrophysical Journal*, vol. 832, no. 2, 2016, doi: 10.3847/0004-637x/832/2/167.
[44] A. Y. C. Nee, S. K. Ong, G. Chryssolouris, and D. Mourtzis, "CIRP annals - manufacturing technology augmented reality applications in design and manufacturing," *CIRP Annals - Manufacturing Technology*, vol. 61, no. 2, pp. 657–679, 2012, doi: 10.1016/j.cirp.2012.05.010.
[45] E. Ai-Lim Lee, K. W. Wong, and C. C. Fung, "How does desktop virtual reality enhance learning outcomes? A structural equation modeling approach," *Computers and Education*, vol. 55, no. 4, pp. 1424–1442, 2010, doi: 10.1016/j.compedu.2010.06.006.
[46] X. W. S. K. Ong and A. Y. C. Nee, "A comprehensive survey of augmented reality assembly research," *Advances in Manufacturing*, no. December 2015, 2016, doi: 10.1007/s40436-015-0131-4.
[47] S. K. Ong, M. L. Yuan, and A. Y. C. Nee, "Augmented reality applications in manufacturing: a survey," *International Journal of Production Research*, vol. 46, no. 10, pp. 2707–2742, 2008, doi: 10.1080/00207540601064773.
[48] T. Lin, H. B. Duh, N. Li, H. Wang, and C. Tsai, "Computers & education an investigation of learners ' collaborative knowledge construction performances and behavior patterns in an augmented reality simulation system," *Computers & Education*, vol. 68, pp. 314–321, 2013, doi: 10.1016/j.compedu.2013.05.011.
[49] N. F. Saidin, N. D. A. Halim, and N. Yahaya, "A review of research on augmented reality in education: advantages and applications," *International education studies*, vol. 8, no. 13, pp. 1–8, 2015.
[50] J.-S. Park, "All-Glass, large metalens at visible wavelength using deep- ultraviolet projection lithography," Nano Letters, vol. 19, no. 12, pp. 8673–8682, 2019, doi: 10.1021/acs.nanolett.9b03333.
[51] J. R. Li, L. P. Khoo, and S. B. Tor, "Desktop virtual reality for maintenance training: an object oriented prototype system (V-REALISM)," vol. 52, pp. 109–125, 2003, doi: 10.1016/S0166-3615(03)00103-9.
[52] J. W. S. Chong, S. K. Ong, A. Y. C. Nee, and K. Youcef-youmi, "Robotics and computer-integrated manufacturing robot programming using augmented reality: an interactive method for planning collision-free paths," vol. 25, pp. 689–701, 2009, doi: 10.1016/j.rcim.2008.05.002.
[53] M. E. C. Santos *et al.*, "Augmented reality as multimedia: the case for situated vocabulary learning," *Research and Practice in Technology Enhanced Learning*, 2016, doi: 10.1186/s41039-016-0028-2.

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