

Modern learning paradigms: A bibliometric analysis of augmented reality and virtual reality in vocational education

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Abstract: This bibliometric analysis aimed to explore the publication trends of the last decade, especially on modern learning paradigms, focusing on implementing Augmented Reality and Virtual Reality in vocational education. This research specifically addressed the analysis of current technology trends, gaps, challenges, strengths, and opportunities of AR and VR during 2015-2024. This research method used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) procedures to collect data from publications focusing on high-quality research results. The data were analyzed and identified using MS Excel software and VOSviewer to visualize various critical metadata obtained in the Scopus database. Notably, publication trends and distribution patterns, the contributions of authors, the geographical spread of publications, and the identification of significant publication sources were all essentials for analyzing the opportunities and challenges within the context of vocational education. The results of this study identified an augmenting growth of publication trends from 2015-2023, including the country of origin of prominent authors such as Bacca et al. (Spain), Babu et al. (India), and Lerner et al. (Germany), whose research results have been proven to impact the primary reference in the field of vocational education in the utilization of AR and VR. They are widely cited and have become the primary references for other authors. Consequently, this bibliometric-based research underscores the potential of AR and VR technologies to improve vocational education by enhancing motivation, educational access, personalized learning, collaboration, and reducing operational costs.

Keywords: Media technology; TVET; Emerging technology; Publication trends; Quality education

1. Introduction

The development of science and technology in the industrial era 4.0 includes a variety of creativity and innovation in changing the pattern of human life at work ([Gajdzik & Wolniak, 2022](#); [Sima et al., 2020](#)). Notably, integrating these technologies encourages access to relatively modern education and improves the quality of learning in vocational education. Moreover, the emergence of accelerated digitalization, especially in vocational education, encourages many teachers and researchers to strengthen learning accessibility by providing a more immersive and interactive

learning experience (Mhlongo et al., 2023; Timotheou et al., 2023). Accordingly, one of the emerging technologies in this decade is Augmented Reality (AR) and Virtual Reality (VR), which are technologies that are often utilized as learning media by creating a digital environment interactively in overcoming conventional learning gaps (AlGerafi et al., 2023; Childs et al., 2023; Xiong et al., 2021). These technologies are considered innovations with promising future novelty values targeted for overall evaluation.

However, study indicates that contemporary controversies associated with adopting AR and VR technologies face specific constraints and difficulties, primarily in funding and execution (Criollo-c et al., 2024; Samala et al., 2023). They include, a survey of vocational education research shows that most schools and educational institutions do not have the resources to use AR and VR technologies (Raji, 2019; Scheid, 2018). Concerning the ability and skills of teachers to incorporate these technologies into the curriculum. Conversely, despite these limitations, there are promising opportunities to integrate these technologies, primarily through cooperation between private-sector partnerships and industries with resources that schools and educational institutions can expertly utilize. Thus, this concern can be overcome by working together to gain access to AR and VR technologies at a more affordable cost and access to specialized training in implementing these technologies in the vocational education sector (Scheid, 2018; Soliman et al., 2021).

AR is a technology that integrates digital components with the physical world, typically through visualizations displayed on a smartphone (Samala et al., 2024). When the smartphone's camera employs a tracking system, either Marker-based or Markerless, it can generate a 3D object within the natural environment (Fortuna et al., 2023; Samala et al., 2024; Waskito et al., 2024). In short, students direct their smartphone cameras toward a textbook fequipped with AR technology (Prasetya et al., 2024), they can see 3D objects appear, which deliver information through animations to clarify vocational learning concepts. This integration of AR technology in vocational education is demonstrated in Figure 1.



Figure 1. AR using smartphones in vocational education

Subsequently, the utilization of VR in the realm of vocational education is described as a technology that combines digital elements with the real world, allowing users to see a variety of interactions that are more immersive, interactive, and simulative (Pellas et al., 2021; Radianti et al., 2020). In a way, the benefits of this technology are no less critical than AR, as VR provides many exciting offerings in terms of a more realistic and real-time learning experience (Remolar et al., 2021).

Notably, VR allows learners to actively engage in real-world simulations without having to be in the actual physical environment, so this technology provides various opportunities for users to learn more practical skills in a more controlled and safe virtual environment for both face-to-face and online learning (Prasetya, Fajri, et al., 2023; Prasetya, Fortuna, et al., 2023; Refdinal et al., 2023). Additionally, VR can simulate more complex learning scenarios that are risky to replicate in reality. For instance, in mechanical engineering training or the medical field, VR can train students in highly skilled situations without posing risks to equipment or individual safety. This benefit can help improve students' competence and confidence before they move on to real-world practice. The use of this technology can be seen through the demonstration results of the Oculus Rift device in Figure 2.



Figure 2. Virtual reality utilizing Oculus Rift in vocational education

These technologies offer great potential in the future, especially in vocational education, which focuses on developing learners' practical skills (Ahmad, 2020; Spöttl & Windelband, 2021). On the other hand, this technology provides a work simulation picture that is relevant in training students' competencies to enter industries requiring high accuracy and work safety, such as engineering, automotive, information technology, health care, or construction. Overall, the output of vocational education is designed to fulfill the needs in the world of work with the best quality of human resources, skills, and extensive knowledge and insight needed to achieve their career targets in the future.

Even though many studies have identified and evaluated the effectiveness of AR and VR in general education, there is still a lack of information regarding implementing these technologies in vocational education (Alalwan et al., 2020). The development of AR and VR applications have a fundamental role in understanding publication trends, collaborations, contribution impacts, challenges and gaps of the most prominent research topics in this context (Zhang et al., 2020). More profound identification of shortcomings, strengths, and potential for further development is carried out through bibliometric analysis mapping the latest scientific publication trends in the last decade (Guray & Kismet, 2023; Majid et al., 2024).

In order to obtain accurate and precise analysis results, this study focuses on examining research topics on the use of AR and VR in vocational education, including analysis of publication frequency, collaboration between research and institutions, keyword analysis, and how the results of the geographical distribution of this research in the form of network visualization. In addition, the

assessment of gaps in the literature obtained based on the data collection results will be further explored from the perspective of opportunities and recommendations for future research so that these benefits can improve the integration of AR and VR in vocational education. Accordingly, the results of the formulation of recommendations through the findings of this bibliometric research provide valuable insights for educators, researchers, and practitioners of vocational education in utilizing AR and VR technology optimally and can be a reference for policy makers. Overall, this study succeeded in formulating several research questions to achieve the research objectives. The following are the questions to answer:

- RQ1. What are the top publications cited in augmented and virtual reality-based learning in vocational education over the past decade, and what is the distribution of publications by subject area?
- RQ2. What are the trends and distribution of publications related to AR and VR in vocational education, and what countries contribute the most and are the most relevant publication sources?
- RQ3. Who are the top 10 prolific authors contributing to research on AR and VR in vocational education?
- RQ4. What are the main gaps and challenges identified through the main keywords in using AR and VR in vocational education?
- RQ5. How do AR and VR technologies' strengths and opportunities impact vocational training and learning?

2. Methods

Research procedure and design

This study aimed to explore research publication trends in the last decade from 2015-2024, especially in modern learning, focusing on identifying publication trends and distribution, research gaps, and challenges in using AR and VR in vocational education. This study utilized the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) procedures ([Page et al., 2021](#)), which provide a systematic framework for identifying research gaps, screening, eligibility, and reporting data findings, as well as providing deeper insights into the use of these technologies using bibliometric analysis.

Furthermore, this study presented a detailed research procedure with several stages. Firstly, data collection was based on relevant academic sources, especially when retrieving data from the Scopus database. Besides, the data collected was filtered based on inclusion and exclusion criteria, with an appropriate research focus for analysis. After that, the results of the publication screening were analyzed bibliometrically to identify trends in the research literature, particularly on AR and VR in vocational education. Most importantly, it determined the distribution of publications in terms of yearly growth and then identified the topics covered in the literature by using the most commonly used keywords, helping to explore research gaps and challenges. Ultimately, this stage was the most crucial, mainly when the bibliometric analysis results had been successfully displayed; it was imperative to interpret them to offer recommendations for future research, including identifying the strengths and opportunities, as well as exploring the potential for further development of AR and VR in vocational education, thereby creating relevant strategies for the future. Additional insights into this bibliometric research process are visually depicted in the flowchart in Figure 3.

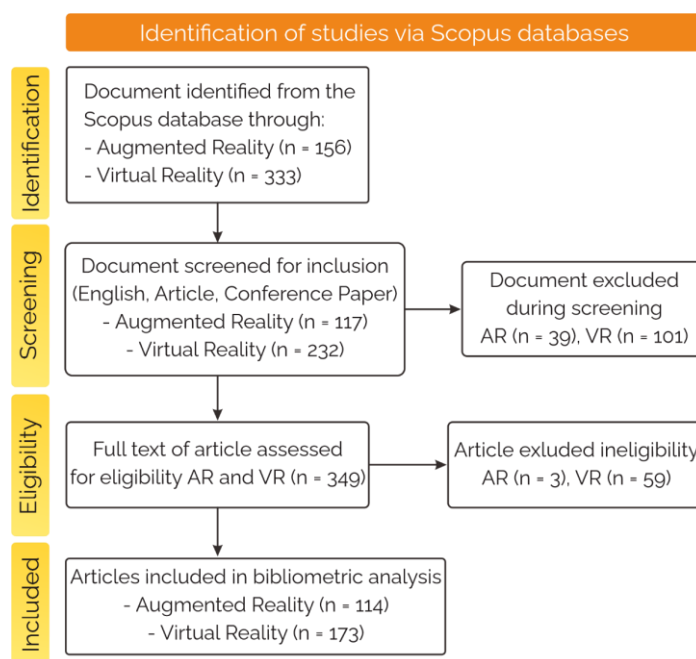


Figure 3. PRISMA procedure

Data collection

The data were collected from the highly reputable international academic database Scopus, using keywords related to "Augmented Reality," "Virtual Reality," and "Vocational Education". The data included information about the publication, such as title, author name, institution, country, journal name, year of publication, and research abstract. For further details, the data collection for this study is presented in Table 1.

Table 1. Details of information from bibliometric data collection

Database from Scopus	
Keyword search: Augmented Reality	Keyword search: Virtual Reality
(TITLE-ABS-KEY (augmented AND reality) AND TITLE-ABS-KEY (vocational AND education)) AND PUBYEAR > 2015 AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE, "conference paper") OR LIMIT-TO (DOCTYPE, "article")) AND (LIMIT-TO (LANGUAGE, "English"))	(TITLE-ABS-KEY (virtual AND reality) AND TITLE-ABS-KEY (vocational AND education)) AND PUBYEAR > 2015 AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE, "article") OR LIMIT-TO (DOCTYPE, " conference paper")) AND (LIMIT-TO (LANGUAGE, "English"))
114 documents found	173 documents found
Duration (year): 2015 – 2024	

Data analysis technique

The data analysis technique in this bibliometric research used descriptive analysis using MS. Excel software and VOSviewer, which is an application used to create visual maps of bibliometric data, such as citation networks, collaboration between authors, and keyword analysis in looking at current research gaps (McAllister et al., 2022). Citation network analysis helped to determine the relationships between publications through citation links, focusing on the top 10 publications from reputable journals and the most cited articles from the last decade. Moreover, author collaboration analysis examined the contributions and partnerships among authors, focusing on AR and VR in vocational education. Finally, the keyword analysis used VOSviewer to visualize the most

commonly occurring keywords, providing a basis for interpreting research gaps and identifying opportunities for future studies in vocational education.

3. Results and discussion

Most cited publication types

RQ1. What are the top publications cited in augmented and virtual reality-based learning in vocational education over the past decade, and what is the distribution of publications by subject area?

This bibliometric research examined and reviewed 114 papers on AR and 173 papers on VR, especially in vocational education, and information on the number of citations received in the last decade (2015-2024). The data collection results were further identified based on inclusion and exclusion criteria by determining conference papers and articles to be the type of publication discussed in this study. The visualization based on the types of AR and VR publications in vocational education is depicted in Figure 4.

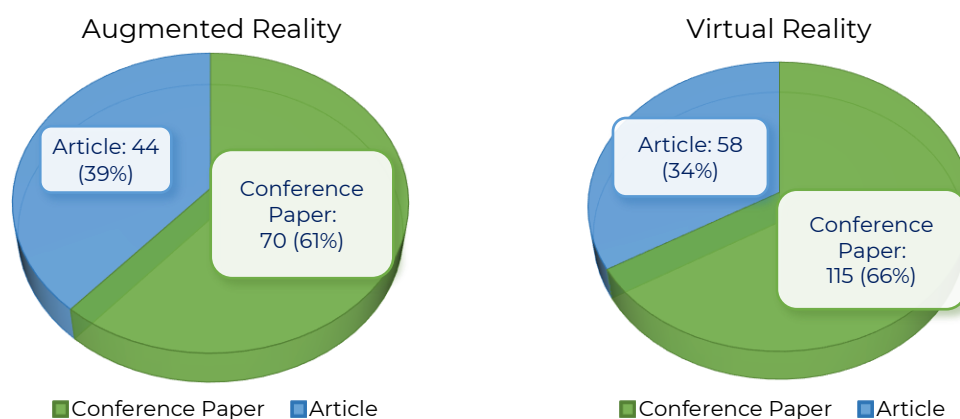


Figure 4. Type of publication: conference papers and articles (2015-2024)

Figure 4 shows the percentage of the use of AR technology in studies (Article: 39% and Conference Paper: 61%) and the rate of VR technology utilization in studies (Article: 34% and Conference Paper: 66%). Hence, AR and VR technology are used more in conference paper publications than in Articles.

In Table 2, there are publications utilizing AR technology in vocational education with the type of publication in conference papers (70) and articles (44). In contrast, the findings we obtained from utilizing VR technology in vocational education and the publication type in conference papers (115) and articles (58) show that the frequency of VR research types is higher than AR. Conversely, the overall average distribution of AR publications (20.37) is relatively higher than VR (14.79), especially in conference papers and articles. However, the content of article publications shows better quality, so they get more citations than conference papers. For more details, the distribution of the data which have been summarized by publication type and distribution considering all citations are presented in Table 2.

Table 2. Data distribution of types of publications with the highest citation

Publication type	Frequency		Number of citations		Average	
	AR	VR	AR	VR	AR	VR
Conference paper	70	115	444	368	6.34	3.20
Article	44	58	561	672	14.03	11.59
Total	114	173	1011	1040	20.37	14.79

Briefly, AR and VR have significant representation in vocational education research, where articles have higher citation averages than conference papers. These findings highlight AR and VR technologies' growing interest and impact in vocational education. Figure 5 presents a line graph depicting the publication trend of conference papers and Scopus database-indexed articles related to AR and VR in vocational learning from 2015 to the projection point in 2024, which is shown to significantly continue to increase based on the number of citations until 2023.

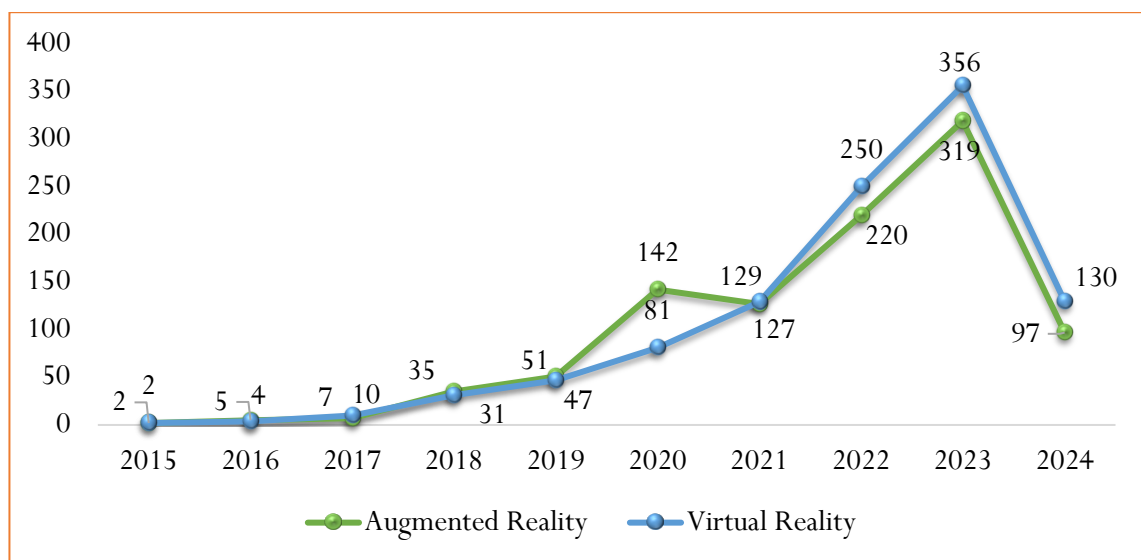


Figure 5. Average citation of all documents per year

Moreover, the trend of AR publications started modestly in 2015, with a negligible number of significant citations. Over the years, there was a significant increase around 2021, when AR publications began to outnumber VR publications. The peak came in 2023 in which AR reached a significant citations of 356. Meanwhile, VR publications show a more consistent upward trend from 2015, started by around ten significant citations. This growth continued steadily without dramatic spikes, peaking at around 319 significant citations in 2023. Similar to AR, VR publications were also projected to experience a substantial decline in 2024.

The graph shows that while AR and VR have become areas of increasing interest and research, AR has experienced a more volatile trend with more significant increases and projected decreases. In contrast, VR has maintained a more stable growth pattern. Meanwhile, the projected decline for both technologies in 2024 was due to various factors, such as shifting research priorities, technological advancements, and incomplete data, as we took the final tally to May 2024. Nevertheless, it is predicted that the trend of educational research implementing AR/VR technology will continue to rise in the next few years.

Moreover, besides outlining the various types of publications found in vocational education over the past decade, the subsequent analysis delved into the distribution of these publications by subject area based on prior research findings. The pie chart in Figure 6 illustrates the use of VR across different academic fields, highlighting computer science as the dominant discipline in vocational education. The chart indicates the relative significance of each scientific field's utilization of VR.

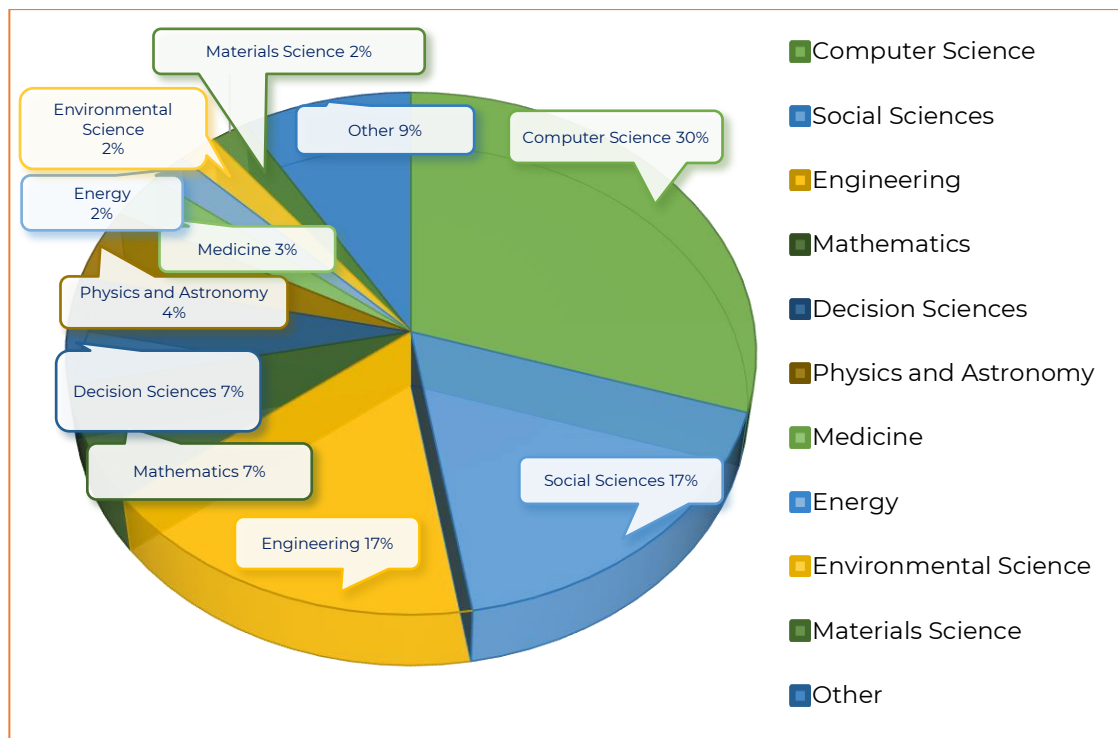


Figure 6. Proportion of VR utilization in each field of vocational education

In Figure 6, the proportion of VR usage is dominated by "Computer Science" at 30%, which plays a fundamentally central role in developing and applying VR technology. After that, the fields of "Engineering and "Social Sciences" contributed 17% of VR utilization. This indicates that VR is crucial not only in engineering disciplines but also in the implementation of social research. On the one hand, other prominent fields, such as "Mathematics" and "Decision Sciences," both at 7%, show the engagement of these disciplines with VR for analysis and problem-solving purposes. On the other hand, the field of "Physics and Astronomy" represents 4%. In comparison, "Medicine" represents 3%, reflecting the growing impact of VR in scientific research and healthcare.

Although there are smaller proportions, especially in "Energy," "Environmental Science," and "Materials Science," with aspects of 2% each, which is assumed to indicate the specific implementation of VR in each of these fields, finally, the "Other" category includes fields that are not individually defined, however still contribute to the diverse VR application landscape. In summary, the pie chart underscores the interdisciplinary nature of VR, which has a significant impact ranging from the core computer science field to more outward applications such as engineering, social sciences, and other fields.

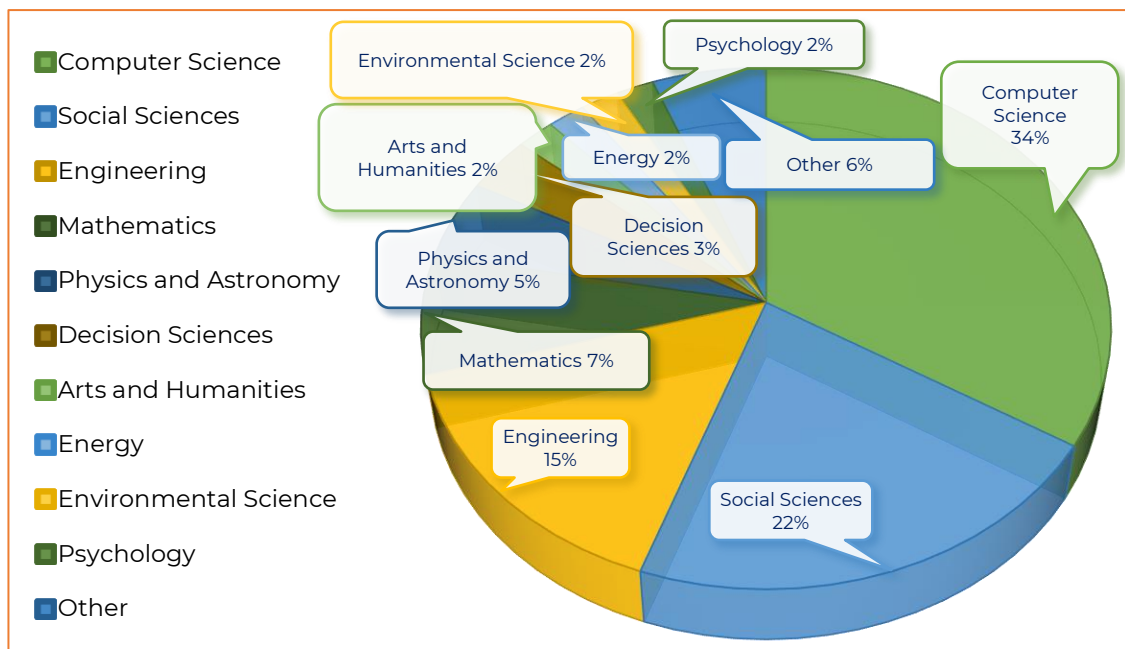


Figure 7. Proportion of AR utilization in each field of vocational education

Figure 7 depicts a visual representation of the utilization of AR in various fields, especially the most dominating aspect, "Computer Science," with the most significant contribution of 34%, highlighting the leading role in the development of AR technology in vocational education. In addition, the use of AR in various sciences shows interesting variations; notably, "Social Sciences" occupies a composition of 22%, which reflects the significant integration of AR in fields such as psychology, sociology, and education, where this technology can increase access to learning to be more interactive and support the renewal of research on social behavior. The field of "Engineering" also has a leading role at 15%, reflecting the use of AR in design, simulation, and structured manufacturing processes.

Meanwhile, "Mathematics, Physics and Astronomy" has a more negligible contribution, with 7% and 5%, respectively, assuming these concepts have complex spatial relationships supporting education, learning, and research. The field of "Decision Sciences and Humanities Arts" weighs 4%, indicating that AR influences decision-making processes and the creative industry, where visualization and interaction play a fundamental role. These and other fields indicate the potential for utilizing AR in the context of energy to improve efficiency across a wide range of disciplines that are not individually specified.

Trends and distribution of publication

RQ2. What are the trends and distribution of publications related to AR and VR in vocational education, and what countries contribute the most and are the most relevant publication sources?

The distribution of publication results was discussed in more detail by paying attention to the main trends related to AR and VR in vocational education from 2015 to 2024. The line graph in Figure 8 illustrates a diverse distribution each year, with the most significant growth in AR publications starting in 2015, which experienced a significant increase until it reached a peak of around 20 publications in 2021-2022. This increase reflects the trend and interest in utilizing AR in vocational education, which is quite popular as a learning tool.

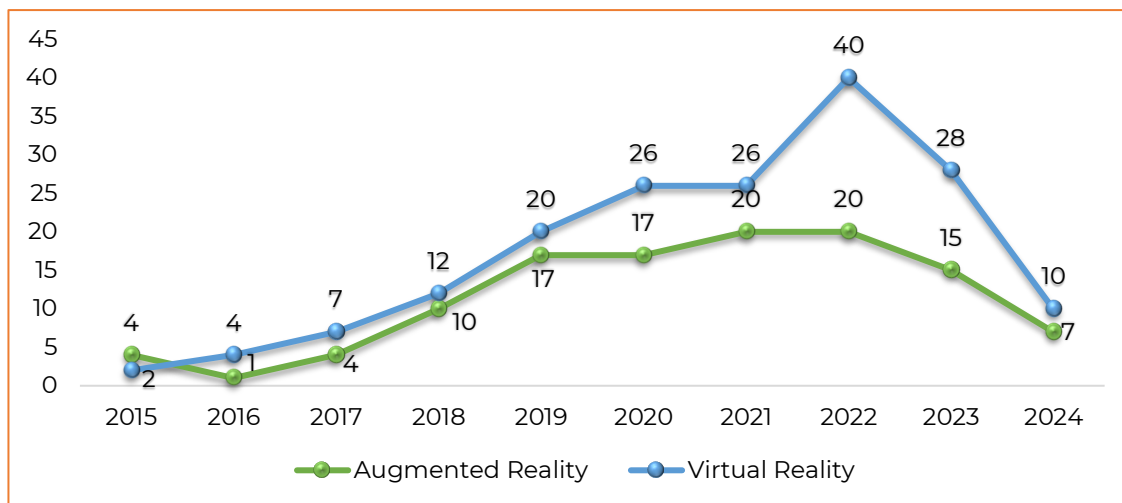


Figure 8. Distribution of publications in vocational education over the last decade (2015-2024)

On the contrary, the highest point of VR in 2022 with 40 publications indicates the adoption of VR is quite popular to develop, especially after Covid-19 became the primary alternative for online-based learning in vocational education. In addition, the number of VR publications reaches the same point at twenty-six in 2019 and 2020, indicating a consistency interest before AR and VR publications started to decline in 2023-2024.

AR and VR technologies have been integrated to vocational education and experienced a more stable increase and subsequent decrease in publications, however it is predicted to rise again. Moreover, more publications on VR could be due to its earlier establishment as a tool for immersive learning experiences. On the other hand, the projected decrease in publications on these two technologies in 2024 is because the data used is still half a year old and will continue to evolve with the combination of integration in Metaverse, Artificial Intelligence, and Mixed Reality towards the renewal of new emerging technologies in vocational education.

In addition to discussing the distribution of publications, an interesting finding from the Scopus database represents ten countries that contribute most to the utilization of AR in vocational education. In Figure 9, the pie chart visualizes the data distribution of the most significantly contributing countries; Indonesia is the primary one, contributing 28% of AR technology, which essentially shows that Indonesia is utilizing AR technology quite a lot in vocational training and education, followed by Malaysia with 17% of doing so. Furthermore, Germany and China also contribute 12% and 9%, indicating their investment in AR as a critical medium in facilitating technical training and development in the industrial world.

The remaining countries in Figure 9, including Spain and the United Kingdom, contribute 7% each. In comparison, the United States is responsible for 6% of AR applications in vocational education. Taiwan and Turkey contribute 5%, and Thailand has the smallest visible share at 4%. Overall, the distribution of contributing countries highlights the global interest in leveraging AR technology to advance vocational education, with countries recognizing the potential of AR to provide immersive and interactive learning environments that can significantly improve skills development and training.

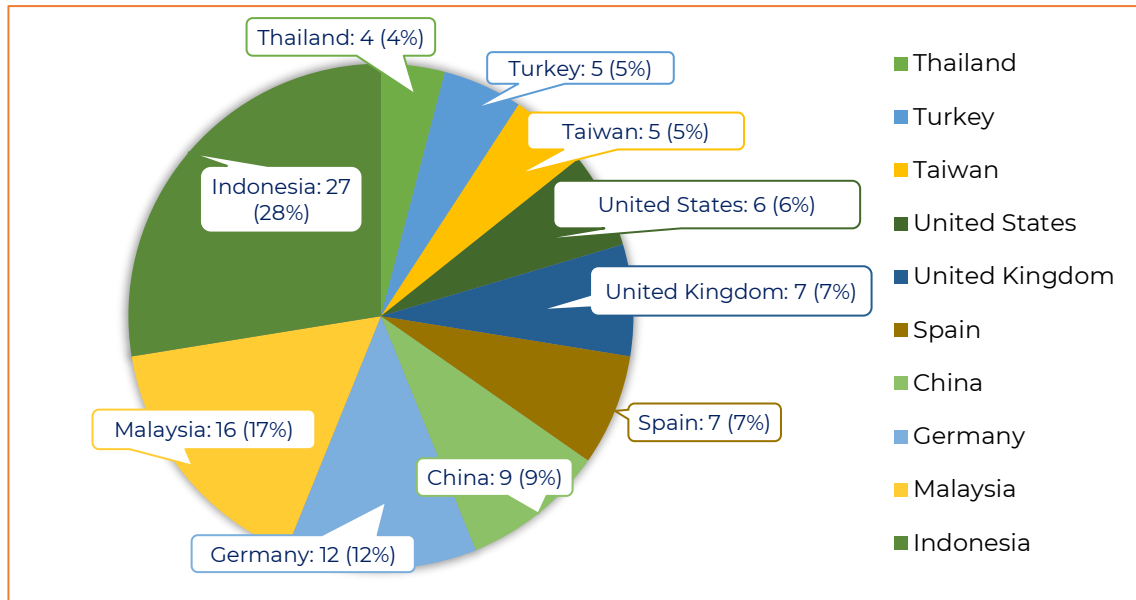


Figure 9. Top 10 countries most publications on AR in vocational education

In Figure 10, an infographic depicts the lines of influence of various publication sources on the quality of AR publications in vocational education from 2016 to 2024. The ACM International Conference Proceeding Series peaked around 2018, showing a significant impact. The Journal of Physics Conference Series shows two peaks, one around 2017 and another in 2021, indicating a period of high influence. The Lecture Notes in Computer Science series, including sub-series in Artificial Intelligence and Bioinformatics, seems to have a declining influence over the years.

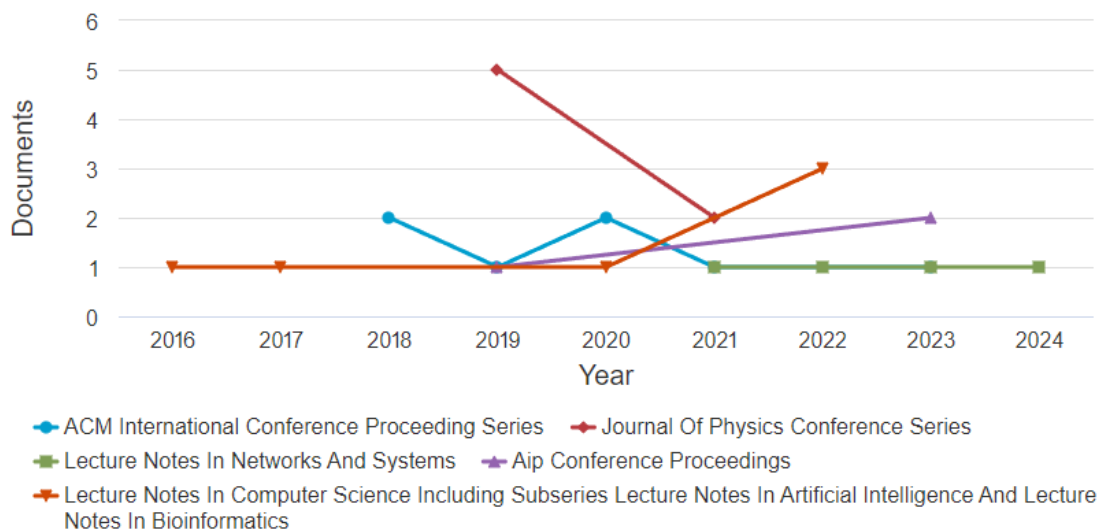


Figure 10. Top five sources of publications on AR in vocational education

In contrast, Lecture Notes in Networks and Systems maintained a stable presence, indicating consistent contributions to the field. Finally, AIP Conference Proceedings fluctuated slightly but showed no clear trend, implying a moderate and variable impact on the quality of AR publications in vocational education. Overall, these sources reflect the dynamic nature of research dissemination and the ever-evolving landscape of AR in vocational education.

As for the countries contributing to the utilization of VR technology in vocational education visualized through pie charts, Figure 11 provides a visual representation. The most significant contributor is China, which accounts for 39% of VR implementation in this sector, highlighting China's leading role in developing and integrating VR technology in vocational training and education. It is followed by the United States, with a contribution of 8%; meanwhile, Germany is behind with 7%. Both countries are well known for their technological advancements. They are proven to implement VR, especially using Oculus Rift devices to enhance the vocational learning experience.

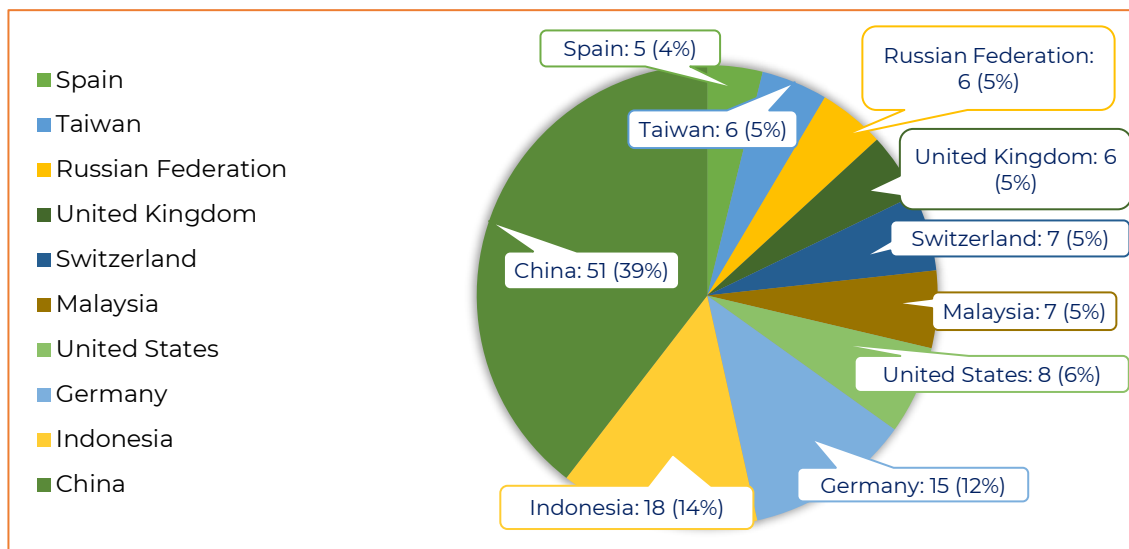


Figure 11. Top ten countries most publication on VR in vocational education

Furthermore, followed Switzerland and Malaysia which contribute 5% of each, showing active involvement in utilizing VR for sustainable education. The UK and the Russian Federation scored 6% of each, while Spain also contributed 5%. Meanwhile, Indonesia stands out with a 14% contribution, strongly focusing on adopting VR technology in its vocational education system. Therefore, the contributions made by these ten countries reflect the global interest in utilizing VR technology to advance vocational education, with countries recognizing the potential of VR to provide immersive and interactive learning environments that can significantly enhance the development of practical skills in training.

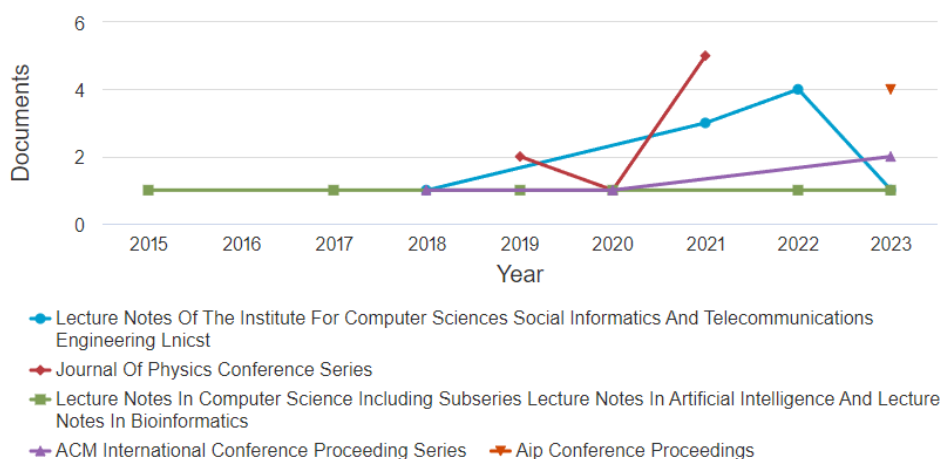


Figure 12. Top five sources of publications on VR in vocational education

Figure 12 presents a line graph illustrating the influence of various publication sources on the quality of publications using VR in vocational education from 2015 to 2023. Lecture Notes of The Institute For Computer Sciences Social Informatics and Telecommunications Engineering LNCS shows a consistent presence over the years, indicating a steady contribution to VR research. The Journal of Physics Conference Series has peaks indicating periods of significant impact, particularly around 2017 and 2021. The Lecture Notes In Computer Science series, including sub-series in Artificial Intelligence and Bioinformatics, seems to have a declining influence over the years. The ACM International Conference Proceeding Series peaked around 2018, signaling a solid impact. Eventually, AIP Conference Proceedings shows slight fluctuations but no clear trend, implying moderate and variable effects on the quality of VR publications in vocational education. Therefore, these sources have diverse and dynamic properties of research dissemination, especially in the evolving landscape of VR in vocational education.

Top 10 most cited authors' publications

RQ3. Who are the top 10 prolific authors contributing to research on AR and VR in vocational education?

Table 3 presents detailed information regarding the authors' most cited documents on AR in vocational education, starting with the top research paper publication by [Bacca et al. \(2015\)](#), published in *Procedia Computer Science* by Elsevier. This research paper has 104 citations according to Scopus and 140 according to Google Scholar, showing its relevant influence in the field of vocational education. The same research document published by the authors ([Bacca et al., 2018](#), [2019](#)) shows a high number of citations, with an affirmation of consistency as the first author who can produce research that has an impact until it is noticed by many researchers at the international level.

Table 3. Top ten most cited authors' documents on AR in vocational education

Author references	Region	Journal & Publisher	Cited by Scopus	Scholar citation
(Bacca et al., 2015)	Spain	Procedia Computer Science (Elsevier)	104	140
(Bacca et al., 2019)	Spain	Australasian Journal of Educational Technology	68	127
(Sirakaya & Cakmak, 2018)	Turkey	International Journal for Research in Vocational Education and Training	58	106
(Bacca et al., 2018)	Spain	Frontiers in Psychology	45	59
(Lee & Hsu, 2021)	Taiwan	Sustainability (Switzerland) MDPI	18	20
(Lester & Hofmann, 2020)	United Kingdom	British Journal of Educational Technology (Wiley Online Library)	17	27
(Zulfabli et al., 2019)	Malaysia	Applied Physics of Condensed Matter (AIP Conference)	16	22
(Alptekin & Temmen, 2018)	Germany	IEEE Global Engineering Education Conference	15	21
(Putra et al., 2021)	Indonesia	International Journal of Interactive Mobile Technologies (ijIM)	13	23
(Pipattanasuk & Songsriwittaya, 2020)	Thailand	International Journal of Instruction	12	20

Furthermore, research by [Bacca et al. \(2018, 2019\)](#) from Turkey, published in the International Journal for Research in Vocational Education and Training, also plays a crucial role with 58 Scopus citations and 106 citations according to Google Scholar. This data shows that their research is valued by both the scientific community and educational practitioners. Additionally, despite having fewer citations, publications by [Lee & Hsu \(2021\)](#) from Taiwan and [Lester & Hofmann \(2020\)](#) from the United Kingdom still made valuable contributions to the literature on AR utilization in vocational education. Meanwhile, studies from Malaysia, Germany, Indonesia, and Thailand are also included in this list, reflecting the global interest and application of AR in vocational education. As a whole, Table 3 highlights the importance of AR in vocational education, especially towards the implementation and contribution of various researchers from around the world in advancing the field of vocational training and education.

Table 4 presents research data by calculating the highest number of citations about VR in vocational education. Initially, the research findings by [Lerner et al. \(2020\)](#), published in JMIR Serious Games, have garnered 43 citations on Scopus and 76 on Google Scholar. This outcome suggests that their study has significantly impacted the scientific community and experts developing VR technology for vocational education.

Table 4. Top ten most cited authors' documents on VR in vocational education

Author references	Region	Journal & Publisher	Cited by Scopus	Scholar citation
(Lerner et al., 2020)	Germany	JMIR Serious Games	43	76
(Babu et al., 2018)	India	IEEE 18th International Conference on Advanced Learning Technologies	40	64
(Smith et al., 2015)	United States	Journal of Vocational Rehabilitation	40	58
(Kim et al., 2020)	Switzerland	British Journal of Educational Technology (Wiley Online Library)	31	58
(Sang et al., 2016)	China	International Journal of Distance Education Technologies	24	31
(Jantjies et al., 2018)	South Africa	ACM International Conference Proceeding Series	22	70
(Pletz, 2021)	Germany	International Journal of Emerging Technologies in Learning	20	27
(Beh et al., 2022)	Malaysia	Engineering, Construction, and Architectural Management (Emerald Insight)	18	25
(Chen et al., 2018)	China	Eurasia Journal of Mathematics, Science and Technology Education	17	44
(Noble et al., 2022)	United States	International Journal of Educational Technology in Higher Education (Springer Open)	13	27

Afterward, according to [Babu et al. \(2018\)](#) from India and [Smith et al. \(2015\)](#) from the United States both have 40 Scopus citations, showing strong influence in advanced education technology and vocational rehabilitation. In contrast, the research results by [Kim et al. \(2020\)](#) from Switzerland

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visualization provided by Figure 14 provides a graphical representation of the evolution and relationship of various terms in education and technology, highlighting the main trends and focus areas from 2019 to 2022.

Based on the interpretation of keywords in the form of clouds and networks in Figures 13 and 14, overall, there are certainly gaps and challenges in vocational education, especially in terms of curriculum alignment with industry needs and evolving technologies. The keyword cloud in Figure 13 shows some exciting keywords such as "Training," "Vocational Education," and AR/VR technology, which continues to evolve into the main focus in preparing practically skilled students who understand how to implement the latest technology. However, the network in Figure 14 reveals research gaps that occur each year from 2019 to 2022 and has a connection between the concepts taught based on the world of work that changes yearly.

On the one hand, the main challenge from this bibliometric analysis is the need for rapid adaptation for vocational education curriculum developers to follow the trend of scientific and technological developments to be at the forefront. Some critical coverage of increased flexibility in learning methodologies and continuous updating of educational materials, especially in information technology, engineering, and vocational education, must be ready to anticipate future trends by prioritizing student needs and equipping students with relevant skills.

Additionally, the interpretation of the keyword distribution network shows that the collaboration between vocational education institutions and industry still needs to be improved, especially in curriculum adjustment and internship programs. Moreover, the emergence of an independent internship program from the Indonesian Ministry of Education is an opportunity to increase students' accessibility to their field experience by directly implementing the knowledge they have gained ([Farida et al., 2022](#); [Harmanto et al., 2022](#)). Align with it, the cloud and network interpretations highlight the importance of innovation in vocational education to address the gap between education and workplace needs. Addressing this challenge will lead to more collaboration between educators, policy makers, and industry to ensure that vocational education remains relevant, interactive, and practical in the face of changes in the world of work.

Strength and opportunities of AR and VR in vocational education

RQ5. How do AR and VR technologies' strengths and opportunities impact vocational training and learning?

In addressing the research questions concerning the strengths and opportunities presented by AR and VR technologies in vocational education, intriguing findings emerged regarding the benefits derived from the implementation of AR in vocational training. One of these strengths is enhancing student motivation ([Bacca et al., 2015, 2019](#)). Conversely, studies highlighting the strengths and opportunities in the context of multi-user VR simulation training have the power to demonstrate the experience of presence and indirectly influence the cognitive learning process, resulting in better learning outcomes for students ([Lerner et al., 2020](#)). Additionally, the main strengths of AR and VR, in general, are creating. For example, AR technology can visually overlay real-time information against actual equipment or objects and develop students' insight, understanding, and retention of the information acquired ([Oke & Arowoia, 2022](#); [Syed et al., 2023](#)). Meanwhile, VR technology immersively allows students to engage in complex simulations, such as machine operations or complicated practical tasks, without the risk of accidents and equipment damage ([Valentine et al., 2021](#)).

Nonetheless, the accessibility offered by AR and VR technologies has a wide range of opportunities to increase access to high-quality education and training without geographical limitations ([Garlinska et al., 2023](#)). Notably, learners from remote locations can access the same training modules available in leading urban training centers. In addition, AR and VR enable personalization of learning, where training content can be tailored to meet individual learning needs, accelerating the learning curve and increasing learner motivation ([Huang et al., 2023](#)). Furthermore, AR and VR technologies provide opportunities to integrate real-time feedback in the learning process, indicating that learners can receive immediate feedback on their actions and decisions in training sessions ([Lee & Hsu, 2021](#)). This opportunity will help correct mistakes quickly and reinforce learning through repetition and immediate correction.

The use of AR and VR in vocational training also enhances collaboration and communication between learners, regardless their physical location ([Pidel & Ackermann, 2020](#)). Learners can collaborate in a virtual environment, collaborate on projects and tasks, and even carry out simulated group work. These interactions are invaluable in developing social and teamwork skills essential in many industry sectors. In addition, adopting AR and VR in vocational education allows educational institutions to reduce operational costs ([Noghabaei et al., 2020](#)). Virtual simulations lessen the need for expensive physical materials and equipment. They could reduce the risk of accidents, saving on insurance and maintenance costs ([Javaid et al., 2023](#)).

Ultimately, the widespread use of these technologies optimizes the learning process and helps prepare learners to adapt to future technologies. Notably, in the world of work increasingly relying on advanced technology, having expertise in virtual and augmented technology makes this a precious asset in adding value to the professionalism of learners. Consequently, through the advanced simulation process and the rich learning experience of visuals and simulations, learners are expected to develop skills relevant to the current and future job market, getting them ready for the challenges of modern industry.

4. Conclusion

This bibliometric analysis research thoroughly explores the trends and developments in utilizing AR and VR in vocational education over the past decade, from 2015 to 2024. The findings obtained in this bibliometric analysis research are firstly related to the distribution of the top publications, which reveals the importance of AR and VR publications that are widely used in Interdisciplinary sectors that include not only technologies in the fields of Computer Science or Engineering but also essential sectors of Social Sciences, which indicates the need for relevance in any Vocational Education intervention ([Baccassino & Pinnelli, 2023](#); [Pinnegar & Cutri, 2022](#)). Regardless the relatively broad distribution trends of AR and VR technologies, the use of VR seems to be more dominant in the number of publications and broader scientific fields. Conversely, AR tends to have a relatively higher average of citations per publication.

Subsequently, the publication trend shows a significant increase starting from 2015, peaking in 2021-2022, especially for AR and VR. The distribution of the most contributing countries also highlights the global interest in utilizing these technologies, especially countries such as China, Germany, and the United States, which are the countries with the most significant contributions in VR publications, while Malaysia and Indonesia have significant contributions in AR publications. In addition, the findings of this study identified the top 10 most contributing authors with the top number of citations on the utilization of AR and VR in vocational education. These authors come from countries such as Spain, the United States, Germany, and India, which play fundamental roles in developing and expanding this research.

Meanwhile, AR and VR technologies have much vocational potential, but some gaps and challenges exist. The challenges include curriculum alignment with industry needs and rapid adaptation to technological developments. On the other hand, gaps in collaboration between vocational education institutions and industry must also be improved to address the evolving training needs of the future. In addition, these technologies can create realistic and interactive learning environments by immersively visualizing the experience and accelerating the learning curve. In addition, AR and VR have exciting opportunities, significantly escalated access to education without geographical restrictions, personalization of learning, and integration of real-time feedback in the learning process.

In conclusion, this study highlights the great potential of AR and VR in improving vocational education. It identifies the need for further research, collaboration between researchers, educators, and industry, and curriculum development, responding to emerging technologies. By strategically leveraging AR and VR, vocational education can become more adaptable to future requirements. In equipping students with the skills necessary to navigate technological transformations and seamlessly transition into the industrial sector, fostering attributes like integrity, teamwork, collaboration, and strong decision-making abilities is crucial.

Implications and recommendations

This research suggests that vocational education institutions and policy makers consider AR and VR effective and innovative learning tools. Increasing collaboration between educational institutions and industry will be essential in addressing the gaps and challenges identified in this research. Efforts to address these challenges will result in better quality of vocational education and benefit society. Overall, this technology enables collaboration and communication between learners regardless their physical location, encouraging cooperation and interaction in group-based learning projects.

Future research must focus more on the implementation and evaluation of the use of AR and VR technologies in vocational education. Moreover, it is essential to broaden the scope of bibliometric analysis by including databases like Web of Science, DOAJ, EBSCO, and PubMed to identify effective strategies that can ensure the sustainable positive impact of these technologies in the academic domain. Additionally, government stakeholders should reconsider traditional learning methods, aiming to incorporate AR and VR technologies at a reduced cost. This initiative can support vocational schools and educational institutions in accessing updated and renewable learning approaches at more affordable rates.

Author contribution

Aprilla Fortuna: Writing – review & editing, Writing – original draft, Visualization, Software, Conceptualization, Data curation, Project administration. Febri Prasetya: Writing – original draft, Writing – review & editing, Methodology, Formal analysis, Supervision. Amna Salman: Writing – review & editing, Formal analysis, Software, Validation. Amir Karimi: Writing – review & editing, Methodology, Data curation, Validation. Juana Maria Arcelus-Ulibarrena: Writing – review & editing, Formal analysis, Software, Visualization. Juan Luis Cabanillas García: Writing – review & editing, Visualization, Conceptualization Methodology. Ahmad Yusuf: Data curation, Visualization, Resources.

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Conflict of interest

There is no competing interest for all authors.

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