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A systematic review of VR/AR applications in vocational education: models, affects, and performances

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ABSTRACT
This paper presents a systematic review of the application models, affects, and performance outcomes of VR/AR in vocational education. The analysis is based on journal articles retrieved from renowned databases such as Web of Science, Scopus, and EBSCO, spanning from January 2000 to January 2022. It highlights the pedagogical value of VR/AR in teaching, presents the current research status of their implementation in vocational education, and suggests future research directions. VR/AR tools or environments have emerged in the past two decades to enhance vocational education, offering new ways to develop learner's practical abilities and theoretical concepts, innovate teaching methods, and advance vocational education. Although VR/AR is being integrated into classrooms, it is still in its early stages. Future research should focus on multidimensional investigations, cross-curricular integration, immersive training, and evaluating learning outcomes and learners and teachers' in-depth interactions with VR/AR technologies. This paper identifies research gaps, expands the scope, and provides directions for researchers and software designers.

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KEYWORDS
Virtual reality; augmented reality; vocational education; systematic review; 3T model

1. Introduction

Vocational education, characterized by its emphasis on technical skills, heavily relies on practical teaching, with over 80% of technical programs adopting this approach (OECD, 2019). Consequently, vocational education programs tend to be more costly than non-vocational programs (OECD, 2021), primarily due to the need for expensive and cutting-edge equipment. Providing high-quality training equipment poses a significant challenge. Moreover, learners using such equipment often require guidance from instructors, as improper utilization can lead to teaching accidents and equipment damage (Juhana et al., 2020). In light of these challenges, Virtual Reality (VR) and Augmented Reality (AR) have garnered considerable attention in vocational education. VR/AR, as promising tools or learning environments, offer accessible options for skill-specific training, either as supplementary or occasional replacements for traditional courses (TWBG, 2021). By providing immersive experiences and virtual training, VR/AR can enhance learners' interest and improve learning efficiency, while also conserving resources and equipment (Liang & Xiaoming, 2013).

In the past few decades, particularly from 2000 to 2022, there has been growing optimism among scholars regarding the application of VR/AR in vocational education, leading to significant research advancements. Various studies have individually explored how VR/AR technologies support learning and vocational education, providing valuable insights (Barbour & Reeves, 2009; Dalgarno & Lee,

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2010; Merchant et al., 2014; Peterson, 2011). However, a comprehensive systematic review of VR/AR in vocational education is lacking, particularly concerning application models, affects, and performance. Therefore, this study employs a literature review method to analyse existing research findings, aiming to develop a comprehensive understanding of how vocational education utilizes VR/AR models, their affects, and performances, while also providing future directions. The analysis reveals that virtual teaching, simulation of real-world scenarios, and practical training are the primary models of VR/AR application in vocational education. Specifically, virtual teaching significantly enhances learners' autonomy in learning, spatial perception, thinking ability, and concentration. Furthermore, VR/AR applications in vocational education are influenced by factors such as self-efficacy, cognitive load, learning motivation, and curriculum design. Therefore, it is crucial to consider the usability and acceptance of VR/AR by learners and teachers, as well as encourage developers to understand the needs and expectations of learners, designing systems that meet their requirements. In summary, VR/AR has the potential to enhance the effectiveness of vocational education. The subsequent sections of this paper are structured as follows: Section 2 provides the theoretical background, Section 3 presents the method and data sources, Section 4 describes the research results, Section 5 discusses the findings, and Section 6 offers conclusions and limitations.

2. Theoretical background

Based upon the TOE (Technology-Organization-Environment) framework (Tornatzky et al., 1990) and the Microsoft K-12 education digital transformation framework (Microsoft, 2022), this study proposes a 3T model for analyzing the application of VR/AR in vocational education, as shown in Figure 1. The 3T model includes the dimensions of teaching innovation, technology improvement, and technical support. Teaching innovation includes curriculum, teaching and learning models, and evaluation. Technology improvement focuses on teaching effects and influential factors. Technical support involves leveraging VR and AR technologies to enhance the quality of vocational education.

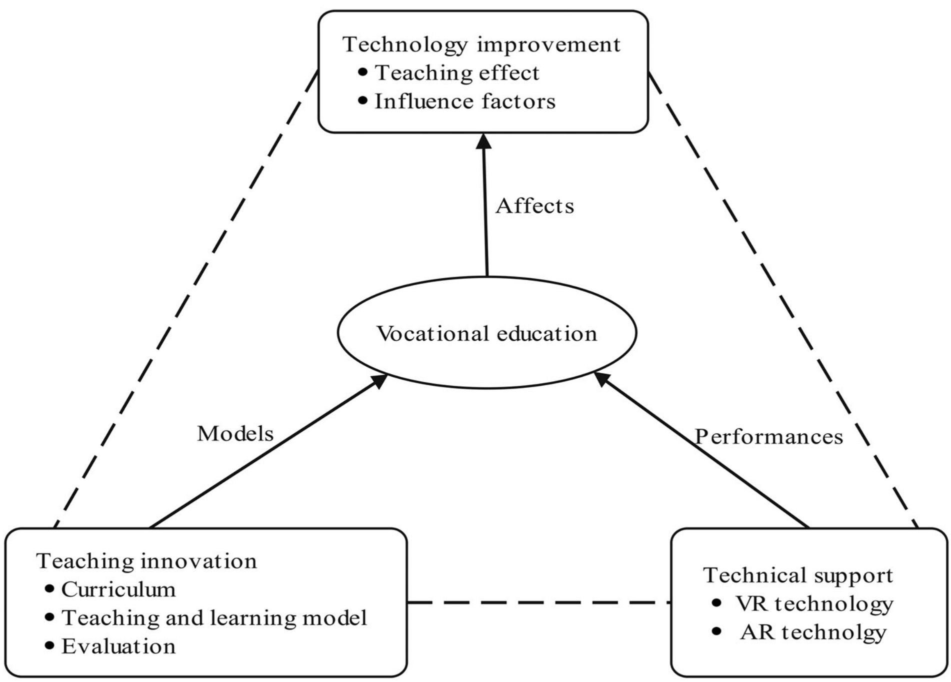

Figure 1. 3T model.

2.1. Teaching innovation: the application model of VR/AR in vocational education

Teaching innovation refers to the integration of VR/AR technologies with vocational teaching classrooms, resulting in the development of application models for VR/AR in vocational education. It serves as a fundamental driving force for the adoption of VR/AR in vocational education and constitutes the primary principle of research and analysis. In teaching innovation, teachers utilize VR/AR technologies to design training courses to develop learners' skills according to the curriculum standards, while learners engage in personalized, multi-scenario simulations and training through interactive VR/AR experiences.

2.2. Technology improvement: affect of VR/AR application in vocational education

Technology improvement involves analyzing the models and performance of VR/AR applications in vocational education to understand their affects on the field. By clarifying the affects of VR/AR in vocational education, it becomes possible to enhance the integration of these technologies with vocational education. This, in turn, improves teaching effects and reduces the influential factors that hinder learners' progress, thereby promoting the development of vocational education.

2.3. Technical support: the application performance of VR/AR in vocational education

VR/AR technology plays a pivotal role in supporting and advancing vocational education. It offers essential prerequisites for investigating the performance of VR/AR applications in vocational education, improving training environments, enriching immersive learning, and delivering authentic scenario-based experiences.

VR is a technology that uses virtual three-dimensional graphics and real-time motion detection to simulate the real world into a virtual world (Ali et al., 2017). In vocational education, learners can engage in theoretical learning and practical operations in a virtual environment through head-mounted displays and handles/controllers. The utilization of 3D modelling software and VR teaching platforms enables interactive learning experiences for learners. The incorporation of VR technology in vocational education enhances learners' sense of immersion, facilitating experimentation, and simulation. Learners are fully immersed in the virtual environment, which enhances their learning efficiency.

AR overlays and connects virtual objects with the real-world environment, enhancing the visual perception of the current view (Azuma, 1997; Azuma et al., 2001). In vocational education, the use of AR helmets and glasses enhances the sense of reality, while AR applications and laboratories offer learners diverse learning experiences and opportunities to acquire various operational skills. Moreover, AR simplifies complex training manuals, alleviating cognitive load for learners during tasks (Upadhyay & Khandelwal, 2018). By incorporating AR, learners can engage with more complex course content and experiments, resulting in increased interest, visual appeal, and comprehension, thereby fostering learners' learning motivation and engagement.

3. Methods and data sources

3.1. Research questions

Through a systematic literature review, this study explores the models, affects, and performances of the application of VR/AR in vocational education. According to the analytical model described the above, the research questions are:

RQ1: What is the primary model to promote the application of VR/AR in vocational education?

RQ2: What affects does VR/AR have on the development of vocational education?

RQ3: What specific performances of designing VR/AR applications in vocational education?

3.2. Research method

Based on the above analysis model, this study aimed to identify relevant literature through search, screening, and evaluation methods to comprehensively analyse the application of VR/AR in vocational education. The research process will consist of six steps: planning, literature search, assessing literature quality, extracting data, integrating data, and writing a review to ensure the rigor and credibility of the research (Dybå & Dingsøyr, 2008; Khan et al., 2001). Literature screening process and results are presented in Figure 2.

3.2.1. Literature search

In this study, the search was conducted using the keywords "VR vocational education" and "AR vocational education" in the Web of Science, Scopus, and EBSCO databases. The search covered the period from January 2000 to January 2022. Within the constraints of limited time and the specified keywords, a total of 516 relevant and valid literature sources were retrieved.

3.2.2. Evaluation of literature quality

Based on the research questions and model, this study developed literature screening criteria shown in Table 1.

In the initial search, 516 articles were found from three databases: Scopus (289), Web of Science (189), and EBSCO (38). The main types of articles are empirical research and journal articles, excluding conference articles. 25 articles with duplicate titles were removed, resulting in 491 articles for further analysis. Using the literature screening criteria, we read the title, abstract, and conclusion, excluding those that did not pertain to vocational education or failed to utilize VR/AR, as well as those that primarily focused on VR/AR itself. As a result, 400 articles were excluded, leaving us with 91 articles that were suitable for inclusion. These 91 articles underwent a comprehensive bibliometric analysis,

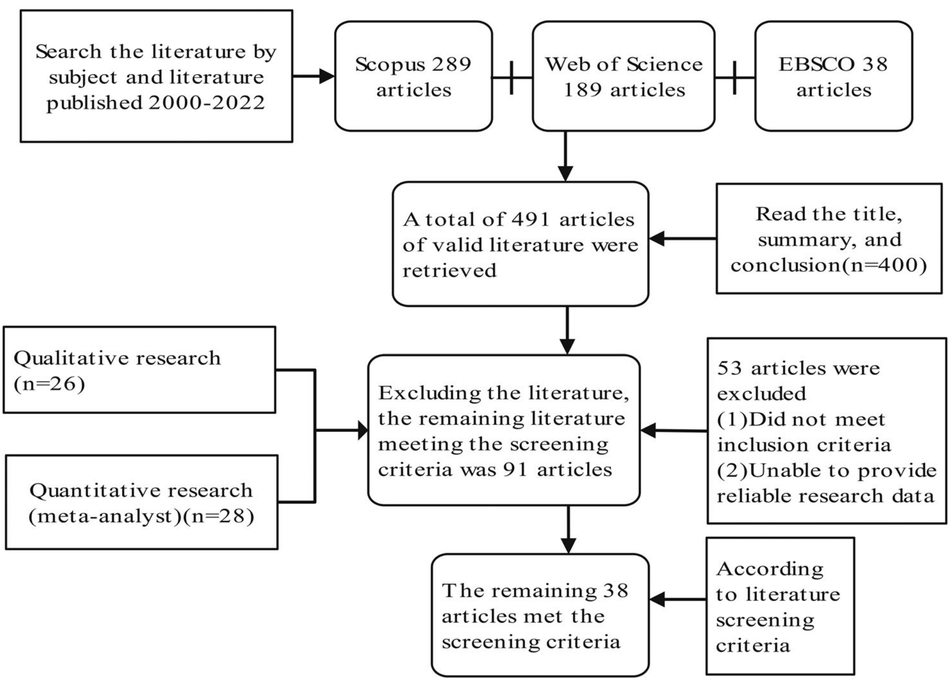

Figure 2. Literature screening process and results.

Table 1. Literature screening criteria.

Number	Included in the standard	Exclusion criteria
1	Non repeated occurrence	To be identified as the sample literature
2	Full text available	Unavailable literature
3	Length 3 pages or more	Less than three pages
4	A paper using empirical research and journal articles	Review papers and meeting articles
5	The research topic is highly related to "the application of VR/AR in vocational education."	The research topic is not related to "the application of AR/VR in vocational education."

evaluating their research purpose, method, data accuracy, validity, and the significance of their conclusions. Articles that met the inclusion criteria but lacked reliable research data were also excluded. Therefore, 38 articles were retained for the final analysis.

3.2.3. Data extraction and counting number of occurrences

This study uses qualitative and quantitative methods to conduct a systematic analysis of 38 literature sources. Through manual analysis of topics, questions, purposes, and critical content, we identified three core categories: models, affects, and performances. Subsequently, we analysed the literature content utilizing a text analysis table to record statistical frequency and detailed information. Disagreements were discussed and processed through iterative revisions, deletions, corrections, and additions and a consensus was reached finally. The research team repeated the process twice to ensure data accuracy. As a result, we identified 7 types and 17 specific items, associated with specifically counting number of occurrences.

The process involved categorizing the studies into models, affects, and performances of VR/AR application in vocational education, and establishing three core attributes. To comprehensively analyse the 38 selected sources, we employed structured, unstructured, descriptive, exploratory, and relevant explanatory qualitative methods, ensuring a multifaceted examination of the topic from diverse perspectives. In terms of models, the application of VR/AR in vocational education was deeply discussed, including curriculum design, teaching model, and research design. Regarding the affects, the evaluation of VR/AR in vocational education was summarized and future development directions was identified. Regarding the performances, a particular emphasis was placed on evaluating outcomes and exploring the extent of VR/AR applications in vocational education. Overall, these identified types and items provide a comprehensive understanding and summary of the research content and findings from the 38 literature sources, offering valuable references and insights for future research, shown in Table 2.

4. Results

This study visually examines evolutionary trends of VR/AR application in vocational education, employing keyword analysis through CiteSpace. In the visualization, each node represents a keyword, with its size indicating its frequency, and the lines represents the symbiotic relationships between them. VR/AR primarily focuses on fields such as 3D models, 3D objects, computer vision, assembly training, and various applications. The research directions mainly focus on medical treatment, the automobile industry, vocational technology, vocational education, vocational training, vocational rehabilitation, cognitive development, cognitive impairment, case analysis, and evaluation, as shown in Figure 3. The application of VR in vocational education commenced in 2005, while the utilization and development of AR gradually emerged in 2013, as shown in Figure 4. Nonetheless, certain limitations persist in the research of VR in vocational education. Conversely, the introduction of AR in vocational education is more detailed than VR. Figure 5 demonstrates the implementation of educational reforms in vocational colleges across various regions, such as North America, Europe, and Asia.

Table 2. Data extraction and count of occurrence.

The core category	Type(No. studies)	Item (No. studies)
Model	Combining classroom and VR/AR (18)	Teaching link design(5)
		learner's participation design(3)
		Experimental flow design(4)
		Practical form(2)
		Experimental effect(4)
	Teaching model(28)	Learning theory(8)
		Learning content(9)
		Learning method(11)
	Research design(22)	Analytical research methods(22)
Affects	Development direction (22)	Prospect and research direction(22)
	Research evaluation (19)	Advantages and characteristics(19)
Performances	Results assessment (21)	Learning ability(5)
		Learning effects(7)
		Overall assessment framework(9)
	Application domain (16)	Applied specialities(4)
		Technology(7)
		Equipment(5)

4.1. Model of VR/AR model in vocational education

4.1.1. Integration of classroom and VR/AR technology

In VR/AR application in vocational education, 6% of the studies focused on mechanical majors, such as virtual manufacturing, maintenance, and assembly. Electronics majors accounted for 29% of the studies, exploring topics like analog circuit design and medical care. Additionally, 6% of the studies centred on logistics, including warehouse management, training, and drills. Finance and economics received 6% of the attention, primarily related to financial training. 18% of the studies concentrated on art and design majors, such as architecture, interior design, and product design. The remaining 35% fell into the category of "other," involving applications like virtual laboratories, virtual games, virtual museums, and virtual surgery simulations.

VR finds utility in logistics and art design majors and AR is used in electronics, logistics and machinery majors. Among the 18 articles reviewed, The main application models are simulated

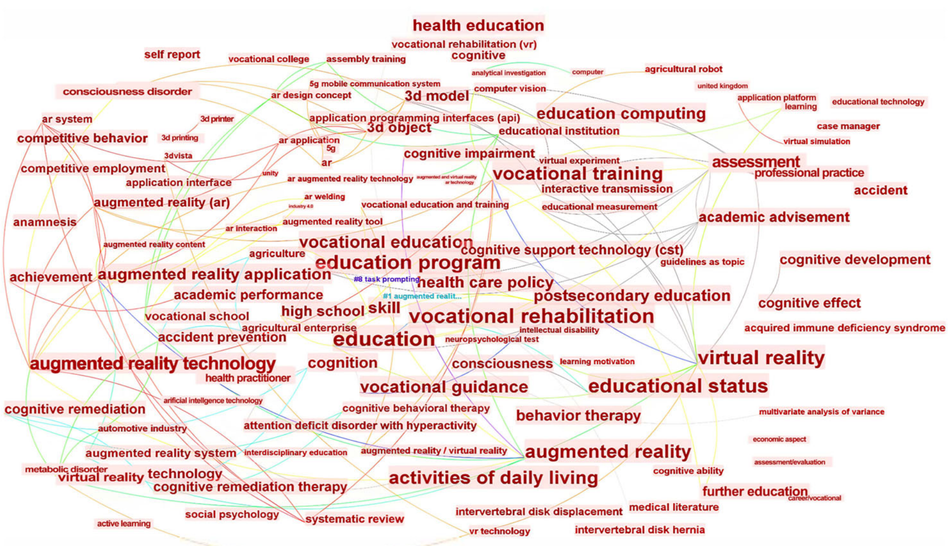

Figure 3. Keywords VR/AR knowledge graph.

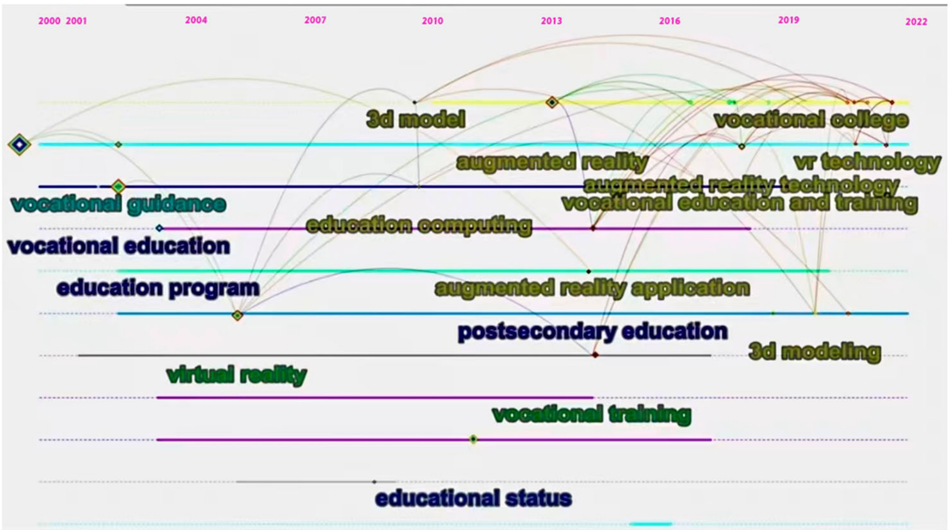

Figure 4. VR/AR development timeline.

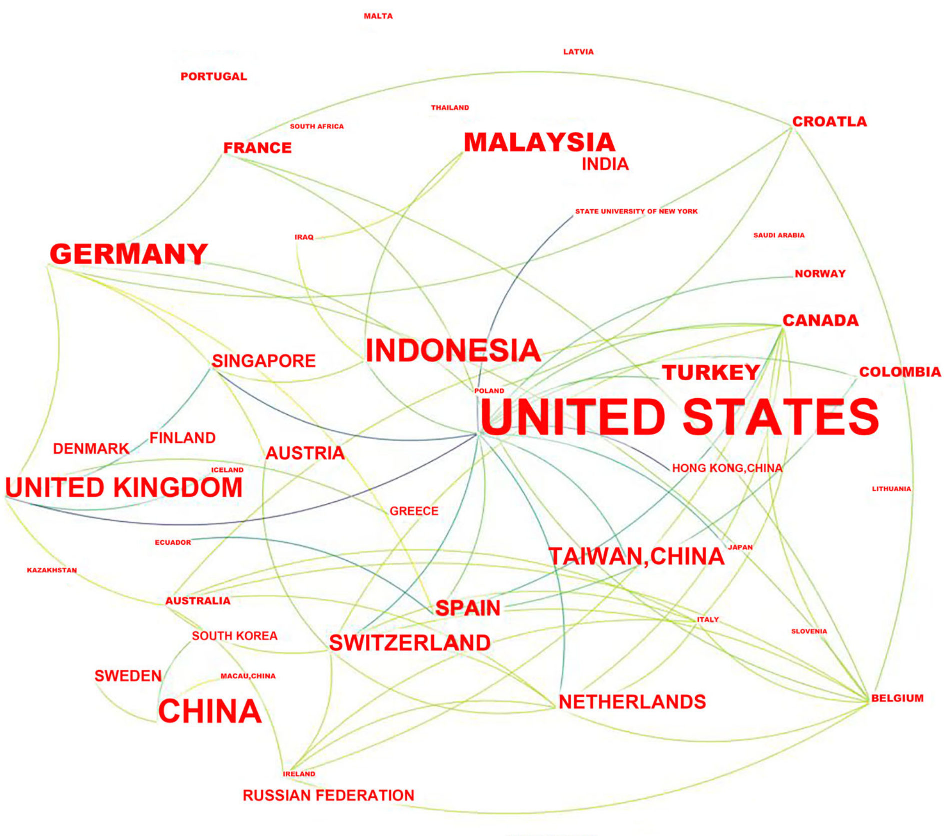

Figure 5. Vocational education development area.

experiments and exercises, as well as virtual teaching. These models provide learners with a personalized and immersive learning experience, enhancing their abilities of autonomy learning, spatial perception, spatial thinking, and concentration. Specifically, VR employs immersive exploration scenes to provide learners with high-quality project operation experiences, primarily in the fields of interior design and construction engineering. On the other hand, AR is leveraged to create realistic experimental settings and enhance learners' practical experiences, particularly in simulated surgery and circuit design. According to Kolb and Fry (1975), learning is not the dissemination and acquisition of knowledge but the process of creating knowledge through transforming experience. The virtual environment can help learners achieve collaborative learning and experimental operations. However, there are still some issues, such as insufficient teachers capabilities, imperfect course designs, and inadequate technical equipment supports. These issues require resolution to further advance the effective utilizations of VR/AR in vocational education.

4.1.2. Teaching model

The data analysis reveals the distribution of articles across some domains. Engineering drawings constitute 6% of the articles, primarily utilized for tool drawings. Electrical engineering encompasses 29% of the articles, predominantly focusing on circuit simulation experiments. Intelligent logistics represents 6% of the articles, applied mainly to operational processes and the creation of realistic scenes. Finance accounted for 6% of the articles, primarily addressing document identification and production. Space design accounts for 18% of the articles, with a specific emphasis on restaurant space design. Furthermore, 23% of the articles pertain to other unspecified learning content.

The literature highlights the prominence of different learning theories in vocational education. Specifically, 21% of the literature focuses on experimental learning and 16% on constructivism and cognitivism. However, it should be noted that 21% of the literature does not provide a more precise analysis, suggesting a need for clarifying which learning theories effectively promote the development of VR/AR in vocational education. In terms of learning content and methods, 18 articles pointed out that vocational colleges prioritize the imparting of theoretical knowledge during classroom teaching, placing greater emphasis on knowledge retention rather than fostering innovation and application of technical skills (Zou, 2021). Therefore, vocational colleges should shift their focus towards effectively teaching learners technical skills, emphasizing practical application and hands-on experience.

Among the reviewed articles, 26 articles specifically emphasize the benefits of using VR/AR in facilitating the acquisition of theoretical knowledge and providing learners with perceptual and experiential training scenarios. Some of these studies adopt Peyton's four learning steps: demonstration, deconstruction, comprehension, and execution (Peyton, 1998). For example, VR simulations are employed to imitate circuit operations in electrical simulation experiments, while AR integrates virtual environments into real-world settings. Particularly in practical teaching, interactive experiences and personalized teaching models are employed to offer learners a novel and immersive learning experience. Teachers are encouraged to integrate various learning resources to design teaching models that align with the learners' needs and educational goals.

The analysis reveals that the most used technologies in the classroom for VR/AR include virtual video, 3D modelling, and wireless technology media. Previous studies have proven that in learner's knowledge acquisition, vision accounts for 83%, followed by hearing at 11%, smell at 3.5%, touch at 1.5%, and taste at 1% (Yang & Cheng, 2020). Therefore, integrating theoretical concepts with VR/AR applications is a crucial stage towards enhancing pedagogical improvements. At the same time, the development of theoretical knowledge and VR/AR is not mutually exclusive but rather a process of mutual promotion and shared growth.

4.1.3. Research design

Figure 6 shows the development trend of VR/AR research in vocational education. According to the result, the predominant research methodology was experimental, using a quantitative approach (*n*

= 14) to test the practical courses studied. It was observed that these experiments also employed pre-test, post-test, or experiment comparison – a combination of questionnaires and experimental tests ($n = 2$). One study utilized a multi-probe design ($n = 1$), wherein the experiment was divided into three phases: baseline, intervention, and maintenance. Another research study applied the ADDIE model method ($n = 1$), comprising the following five phases: analysis, design, development, implementation, and evaluation. However, a majority of the articles ($n = 4$) did not explicitly specify the methodology employed in their studies. Regarding study design, the majority of research focused on model-building ($n = 6$). In most cases, experimental research methods ($n = 8$) were utilized. Some studies employed research frameworks ($n = 3$) or design protocol approach ($n = 5$).

Regarding data collection, 13% ($n = 5$) of the articles measured personalized learning using qualitative, quantitative, and multi-probe design research methods. 20% ($n = 8$) of the articles measured cognitive load, adopted the ADDIE model ($n = 3$), and conducted quantitative research, questionnaires, and interviews. 31% ($n = 12$) of the articles measured feasibility and usefulness. Among these articles, qualitative and quantitative (pre-test and post-test), experimental evaluation, curriculum design framework, questionnaire survey, and interview research were the most widely used methods. 21% ($n = 8$) of the articles measured validity and reliability using qualitative, quantitative, and questionnaire research methods. 15% ($n = 6$) of articles measured immersion and realism using a questionnaire that asked participants to self-assess their engagement and immersion and answer questions about preferences and improvements.

In terms of data analysis, the articles are mainly qualitative and quantitative and use methods such as t-tests, modelling, and analysis of variance for data analysis. Studies have shown that VR/AR technologies offer new possibilities and substantial pedagogical benefits for improving the quality of vocational education and training (Stender et al., 2021). Although there are many examples of research and applications of VR technologies in technical disciplines (Di Lanzo et al., 2020; Radianti et al., 2020), few are devoted to testing and analysis (Bacca Acosta et al., 2014). Valdez et al. (2015) explained that electrical technology experiments could be conducted in virtual laboratories and online learning environments to help learners develop practical skills. A virtual and non-immersive experimental study on electricity was conducted among fifth- and sixth-grade learners, showing that virtual-real experiments can help learners better understand the concept of electricity and establish appropriate learning thinking patterns (Jaakkola et al., 2011).

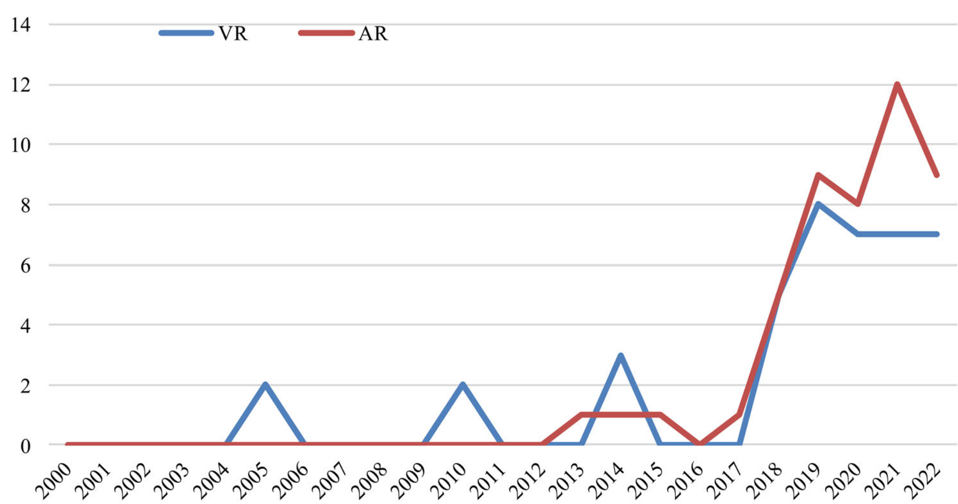

Figure 6. Development trend of VR/AR research.

4.2. Affects of VR/AR in vocational education

4.2.1. Development direction

Upon reviewing the existing literature, it becomes evident that experiments involving the application of VR/AR in vocational education are steadily growing. However, further empirical research is necessary to establish the feasibility of these approaches. Through reviewing the research on application of VR/AR in vocational education, the following future research directions can be identified.

Firstly, the focus area pertains to instructional design for VR/AR in vocational education. Presently, classroom applications primarily involve the experiments of virtual perception and simulated installation. In terms of courses and experiments, VR courses primarily encompass course assessments, course discussions, and intelligent teaching, while AR courses predominantly revolve around design motivation and practical applications. However, there are still several challenges in VR/AR task design that necessitate exploration and improvement. For instance, further research is required to effectively integrate course task design with theoretical knowledge, thereby maximizing the potential of VR/AR in vocational education. Future research aims to concern the innovative curriculum and framework design and seek novel ways to effectively harness VR/AR in vocational education. Furthermore, The integration of VR/AR in the classroom need to invigorate learners' motivation and develop their cognitive abilities, enabling them to acquire knowledge more proficiently. Future investigations will prioritize the development and optimization of VR/AR integration within the curriculum, ensuring its alignment with the essence and objectives of vocational education.

Secondly, there is a need to improve evaluation standards and technical proficiency in vocational education. The focus of evaluation should shift from simply evaluating outcomes to evaluating the impact of experiments on learners and teachers. Based on the evaluation results, corresponding improvement plans should be formulated. In terms of technology, attention should be directed towards interactive technology, application methods, visual effects, as well as other factors such as equipment cost, application environment, and use methods of VR/AR in vocational education. It is recommended to further explore the criteria employed in vocational education to evaluate learners' proficiency in VR/AR technologies. Simultaneously, an analysis of the changes in learners' abilities of application and practice, collaboration, innovation, and thinking when utilizing VR/AR for learning is crucial to better evaluate their mastery of these technologies. Developers must continuously enhance their technical expertise to create high-quality VR/AR applications that align with learners' needs and expectations. Moreover, a thorough understanding of learners' career aspirations, cognitive levels, learning interests, learning styles, and interactive experiences is essential to ensure that developed applications effectively meet learners' needs and expectations.

Thirdly, the innovation of VR/AR in vocational education warrants attention. Based on the aforementioned studies, it is evident that the application of VR/AR in vocational education is still in its nascent stages. Further research and exploration are imperative to enhance the theoretical foundation and teaching practices in this domain. Future research also needs to study the development of intelligent and mobile VR/AR learning in vocational education. Intelligent VR/AR learning entails integrating artificial intelligence to deliver precise and personalized teaching services to learners. Integration VR/AR with intelligent tools will create an efficient teaching environment platform (Luo et al., 2018) that becomes invaluable for learners to conduct practical training and engage in classroom learning. This integration will unlock a wider range of application scenarios and attract enough user groups. Mobile VR/AR learning should aim to facilitate learners' access to learning experiences and flexibility anytime and anywhere.

4.2.2. Research evaluation

During the assessment of the literature's quality, this study excluded numerous articles due to substantial gaps in their experimental design and implementation process, which ultimately led to a lack of practical relevance.

Regarding the design of learning scenarios, only 5% of the literature addresses learners' cognitive abilities and learning styles, describing their learning status and process. Moreover, the final evaluation primarily emphasizes feasibility and innovation. In terms of learning, there are notable observations to be made. Firstly, a large body of literature does not specify the learning theory used. Secondly, the utilization of VR/AR in the laboratory classroom reduces learning accidents and equipment damage. Lastly, most articles only highlight the advantages and future prospects of VR/AR in vocational education, neglecting to address the developmental shortcomings and avenues for improvement.

Of these 38 articles, this study initially selected 16 empirical studies from the sample literature. These articles were then categorized under teaching effectiveness, learning interest, learning motivation, and learning ability. The research subjects include learners, teachers, and specific cohorts. Among these articles, 8 articles investigated learners' self-efficacy and cognitive load in VR/AR learning environments, while 4 articles explored the impact of teachers and learners' cognition in VR/AR learning environment. The findings showed that VR/AR positively impacts learners' self-efficacy. The cognitive load experienced by learners is closely tied to the stress and burden they encounter, and VR/AR technology can effectively alleviate this load. Specifically, AR can help learners enhance their academic performance, theoretical knowledge, and assembly skills while maintaining their self-efficacy (Sirakaya & Kilic Cakmak, 2018). However, a reflective approach to learning has been found to heighten learners' learning effectiveness and self-efficacy while reducing cognitive load (Lee & Hsu, 2021). Furthermore, studies have indicated that integrating AR into classroom learning activities enables learners with higher self-efficacy levels to master more concepts and knowledge (Cai et al., 2019). Armougum et al. (2019) elaborated on the measurement of the cognitive load in VR and suggested a direct association between the learning content introduced in VR and cognitive load. Expertise in the context of cognitive load was influenced by physiological and subjective measures, without differentiating between natural and virtual environments (Armougum et al., 2019). The integration of VR/AR technology in teaching and learning offers opportunities to create learning environments that alleviate psychological stress and tension, reduce cognitive load, and foster positive outcomes through enhanced integration of learning experiences. Research indicates that VR has changed teaching methods by providing enriched content, high-quality interactive scenes, and immersive user experiences (Wu & Fei, 2011). On the other hand, AR emphasizes teaching approaches centred around role, task, and position, aiding learners in comprehending learning content and methods effectively (Wu et al., 2013). AR helps learners learn effectively through visual interaction, theoretical engagement, and information processing (El Sayed et al., 2010). However, limited attention has been given to the teacher's instructional capabilities, teaching resources, and implementation costs in existing studies, with most of them primarily focusing on the feasibility of VR/AR applications.

Our analysis reveals that the application of VR/AR in classroom teaching yields a substantial improvement in learners' learning effects. Compared to traditional courses, learners demonstrate remarkable advancements in both theoretical understanding and practical skills development. This progress can be attributed to their engagement in a highly focused learning environment that capitalizes on the advantages of human–computer interaction. However, to fully realize these benefits, teachers must adopt a targeted approach in designing classroom content and teaching methods, thereby highlighting the heightened demands placed on their teaching abilities and expertise.

4.3. Performances of VR/AR in vocational education

4.3.1. Application domain

VR/AR application in engineering majors encompasses the largest proportion, comprising 38% of the total number of articles, with notable applications in automotive engineering, mechanical design, electrical engineering, computer applications. Natural sciences accounted for 12% of the articles, primarily focusing on chemistry and physics. Medicine, economics, and agricultural sciences accounted for 6% of the articles. The remaining 19% of the articles pertained to other domains.

4.3.2. Results assessment

Out of the 21 articles examined, 10 of them specifically addressed the enhancement of learners' motivation to learn, demonstrating the positive influence of VR on learners' moods and highlighting the significant benefits derived from the combined use of VR and motivation (Allcoat & Von Mühlenen, 2018). Furthermore, AR has been shown to have a positive impact on teaching, as it contributes to the improvement of various aspects such as learning content, spatial structure comprehension, language association, long-term memory retention, collaboration, and learning motivation (Radu, 2012; Radu, 2014). 8 articles have studied the influence of VR/AR on learners' learning outcomes, indicating that AR contributes to the improvement of academic performance (Chang et al., 2015; Chiang et al., 2014). Additionally, learners have displayed positive attitudes towards AR-enhanced learning activities (Lu & Liu, 2015). Furthermore, 15 studies focused on improving the effectiveness and interest of VR/AR technology, revealing that the utilization of VR/AR enhances learners' learning interest, motivation, methods, and effects. Moreover, it promotes interaction and cooperation among learners and fosters an enjoyable experimental learning process.

In studies evaluating VR/AR, it has been observed that 9 papers focusing on personal emotions and engagement exhibit a strong correlation with learning motivation, making them crucial for facilitating effective learning (Pintrich, 2003). This paper posits that future interactive AR technologies should prioritize supporting ubiquitous and informal collaborative learning (Akçayır & Akçayır, 2017). The learning abilities of learners are influenced by factors such as learning style, teaching methods, equipment utilization, and learning attitude. An experimental study assessed the application of VR/AR in vocational education, utilizing 9 samples to derive 6 evaluation outcomes. The evaluation methods employed for VR include formative evaluation, objective analysis, usability evaluation, and case analysis. On the other hand, AR technology evaluation employs techniques such as reliability analysis, quantification through questionnaires, regression analysis, cross-section analysis, brainwave analysis, key influencing factor analysis. Both VR and AR employ reflective evaluation methods and reliability and validity are the most critical evaluation indicators. The outcomes of these assessments emphasize the importance of utilizing reflective assessment techniques in the context of VR/AR. This approach enables learners' active involvement in self-assessment and facilitates the identification of individual learning needs and promotes self-directed learning (Jantjies et al., 2018). Previous studies have utilized the Textbook Motivation Survey (IMMS) tool to evaluate learners' motivation to learn, specifically focusing on dimensions such as attention, relevance, confidence, and satisfaction (Keller, 2010). Overall, the dimensions of confidence and satisfaction tend to exhibit higher scores compared to attention and association dimensions (Bacca et al., 2015; Bacca et al., 2018).

As to the research of application frameworks, there exists a considerable number of research frameworks dedicated to AR applications. However, only several studies takes motivation-related factors into account. For instance, frameworks include those designed for socio-technical courses (Widiaty et al., 2021), 3D virtual labs (Dede et al., 2019), and the AR effective motivation framework (Acosta et al., 2019). Among these, the AR effective motivation framework stands out as a prominent research achievement. This framework describes the current state of education and assists with the application of AR in education. It enables learners to gain a deeper understanding of the learning content, explore and solve problems using multiple perspectives, and receive real-time feedback that would not be attainable in traditional classroom environments. Additionally, teachers can leverage this framework to evaluate existing experimental procedures and design and develop a new one based on the recommendations provided in the framework (Acosta et al., 2019).

VR/AR technologies have potentials for enhancing learners' learning motivation and improving their learning outcomes, while also fostering improvements in attention, confidence, and satisfaction. Self-assessment plays a crucial role in in facilitating learners' progress and optimizing their learning effectiveness. Moreover, VR/AR applications can facilitate the development of interaction, cooperation, and project operation skills, while also expanding learners' thinking capabilities. When designing task-based instruction, teachers should carefully consider the application of VR/AR, taking into account individual differences among learners. This approach entails providing personalized teaching methods and task designs. It is essential for teachers to gain a comprehensive understanding of learners' learning needs and feedback, enabling them to make timely adjustments to their teaching strategies and methods. This proactive approach ensures the continuous improvement of instructional effectiveness and quality.

5. Discussion

This paper examines the application of VR/AR in vocational education, specifically focusing on models, effects, and performances, based upon previous studies. The scope of VR/AR implementation in vocational education continues to expand, necessitating higher standards for simulated course training, learner engagement, reliability, cognitive processes, and practice. VR/AR introduces significant disparities in comparison to traditional teaching environments and methods, as demonstrated in Table 3, which illustrates the evolution of vocational education. By conducting a keyword analysis on research hotspots and utilizing CiteSpace to eliminate irrelevant keywords during the retrieval process, research content unrelated to the topic can be filtered out. The result is depicted in Figure 7.

Multiple studies have shown that active learning benefits learners, suggesting that the advantages of VR align with those of active learning (Pereira-Santos et al., 2019). Other studies have shown that active understanding is sometimes better than passive learning (Haidet et al., 2004). In the learning process, active learning proves to be more efficient than passive learning. Therefore, the use of VR/AR in the classroom can help learners shift from passive to active learning, thereby transforming learning methods. At the same time, teaching of vocational skills serves as a critical intervention for individuals with cognitive disabilities, enabling them to live independently and actively participate in various activities (Chang, Chen, & Chung, 2011; Chang⍰Wang, & Chen, 2011; Chang et al., 2013).

It is worth noting that using VR/AR in classrooms, especially for learners with low spatial cognitive abilities, will be beneficial in reducing the mental burden (Kamińska et al., 2017; Lee & Wong, 2014). On the contrary, the complexity of experimental materials and tasks can result in learners cognitive overload within AR-based learning environments (Cheng & Tsai, 2013), leading to a heightened cognitive load for learners and impeding their learning and experience. Studies have identified potential adverse effects of AR in teaching, including attention tunneling, usability difficulties, ineffective integration within the classroom, and learner differences (Cai et al., 2019; Jantjies et al., 2018). Therefore, it is difficult for learners who passively participate in learning to enhance their analytical and problem-solving abilities.

Table 3. The evolution of vocational education.

Category	Vocational education	Modern vocational education
Current situation	Textbook (outdated) + technology (limited)	Textbooks (continuously updated) + Technology (wide range)
Target	Master basic operational skills and theoretical knowledge	Theory and technology develop together to cultivate operational skills
Teaching method	Single teaching model	In "Online + Offline" mixed teaching mode, some schools have realized VR/AR integration in teaching creates a situation
Teaching concept	Hinder divergent thinking, inhibit learners' personality development	Cultivate creative thinking, promote learners' personality development
Teacher	Rigid teaching, backward thinking, and low theoretical level	High theoretical level, solid practical ability, advancing with the times
Learner	Insufficient ability, weak foundation, and individual differences	Solid "theory + skills" and strong innovation ability

Figure 7. Current research directions and hotspots.

Previous experimental studies have exhibited limited outcomes due to the absence of specific requirements regarding the cognitive level and knowledge base of the research subjects. To enhance the research value, it is imperative to select learners with the same theoretical learning abilities and practical skills as research participants. Furthermore, the selection of teachers should consider their extensive knowledge and instructional capabilities to meet the requirements of VR/AR integration and design of classroom contextualization. Currently, vocational colleges do not impose stringent requirements on teacher selection, and the equipment provided does not align with the teachers' capabilities, resulting in challenges for vocational education reform. Consequently, the criteria for selecting teachers will become increasingly rigorous. For instance, higher vocational colleges may employ intelligent tools such as big data, artificial intelligence, and cloud computing to analyze teachers' abilities and formulate corresponding development directions and recommendations.

Presently, vocational colleges are leveraging advanced technologies such as 5G communication, Internet of Things (IoT), and VR/AR to construct diverse levels and variations of virtual intelligent teacher representations. The primary objective is to augment learners' motivation for learning and foster a stronger sense of identity with the educational institution (Bacca et al., 2018). It is noteworthy that the integration of VR/AR technologies and classroom teaching holds the potential to enhance learners' cognitive and innovative abilities. However, as VR/AR technologies are still in the early stages of development, the majority of technologies implemented in vocational education are considered immature. Consequently, the amalgamation of new technology and educational practices often lacks a comprehensive reflection on both theory and practical aspects, necessitating further research on the fusion of theoretical foundations and VR/AR applications (Aguayo et al., 2017). Another significant limitation lies in the scarcity of data and limited technical resources, which result in less intelligent and comprehensive learning and practice environments. To address this issue, future research in vocational education should explore the incorporation of intelligent tools such as IoT, big data, artificial intelligence, and cloud computing. By combining these intelligent tools with VR/AR, it becomes possible to conduct thorough analyses and statistical evaluations based on learners' and teachers' responses and practical operation abilities. Subsequently, detailed study plans and intensive training programs tailored to each individual learner and teacher can be formulated, leveraging the insights gained from these analyses.

In the future, leveraging the full potential of advanced information technologies will emerge as a crucial developmental pathway for vocational education, marking a significant milestone in promoting the reform and transformation of vocational education. Notably, the synergistic utilization of intelligent tools and VR/AR technologies offers efficient immersive environments and enhances theoretical teaching, facilitating the integration of vocational education with technologies such as the internet, IoT, big data, artificial intelligence, and cloud computing. This integration aims to establish a robust educational and learning platform for both learners and teachers. With the continuous update and iteration of VR/AR technology, researchers will concurrently advance the latest academic research to achieve mutual progress in academic exploration and VR/AR advancements. The ultimate goal is to foster the simultaneous development of learners' theoretical knowledge and practical skills.

6. Conclusion and limitation

Upon conducting a systematic literature review and analysis, certain limitations were identified within our work. Despite the relatively advanced stage of maturity achieved by VR/AR technologies, their application in vocational education still requires improvement, particularly in areas such as scene replication, equipment development, and the costs associated with maintenance and updates. The existing studies predominantly focus on exploring the positive impacts of VR/AR on group-based learner exploration, interaction, and collaboration, while neglecting individual-level research. Notably, there are relatively few frameworks specifically dedicated to VR/AR application in vocational education, which may lead to some omissions in VR research and analysis. In terms of experimental design, the most commonly employed method is quantitative research, yet its singular approach poses certain limitations. For instance, the same study may yield different conclusions based on varying settings, learner and teacher groups, thereby affecting the consistency of the final results and imposing restrictions on sample applicability. Consequently, the current most of literature generally lacks precise solutions.

This paper provides a systematic overview of the application models, affects, and performance outcomes of VR and AR in vocational education. It elucidates the pedagogical value of VR/AR in teaching, presents the current research status of VR/AR implementation in vocational education, and delineates future directions for research and development. Over the past two decades, intelligent tools like VR/AR have emerged to meet the demands of vocational education development and reform, offering more teaching tools to develop learners' practical and theoretical learning abilities, facilitate teacher's instruction innovation, and advance vocational education methods. Although vocational schools have started to experimentally incorporate VR/AR into classroom settings, this application is still in its nascent stages. Future research endeavors should include multidimensional investigations and explorations of innovative teaching methods, cross-curricular integration, immersive training by using VR/AR technologies. It also placed emphasis on evaluating the learning outcomes and learners and teachers' in-depth interactions with VR/AR technologies. This paper points out future improvement and research gaps, expands the research scope, and provides research and design directions for researchers and software designers.

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