The Use of Virtual Reality (VR) Technology in TVET Skills Training: A Systematic Review

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ABSTRACT

Walaupun penggunaan teknologi Realiti Maya (*Virtual Reality*, VR) dalam Pendidikan dan Latihan Teknikal dan Vokasional (TVET) semakin berkembang pesat, kajian yang menghimpunkan secara menyeluruh teknologi yang digunakan serta kesannya terhadap latihan kemahiran masih terhad. Oleh itu, kajian ini bertujuan untuk mensintesis bukti empirikal berkaitan penggunaan teknologi VR dalam latihan kemahiran TVET. Sorotan Literatur Sistematik (*Systematic Literature Review*, SLR) telah dilaksanakan berdasarkan garis panduan PRISMA dengan menganalisis 21 artikel yang diterbitkan antara tahun 2020 hingga 2026 dan diperoleh daripada pangkalan data Scopus, Web of Science dan Google Scholar. Analisis tematik digunakan bagi mengenal pasti jenis teknologi VR yang digunakan serta kesannya terhadap latihan kemahiran TVET.Dapatan kajian mengenal pasti lima kategori utama teknologi VR yang digunakan dalam latihan kemahiran TVET, iaitu *Head-Mounted Display* (HMD), perisian dan sistem simulasi VR, *motion controller*, paparan 360 darjah serta simulasi berasaskan senario. Analisis menunjukkan bahawa simulator VR dan HMD merupakan teknologi yang paling dominan digunakan dalam latihan kemahiran TVET. Selain itu, lima kesan utama penggunaan VR turut dikenal pasti, iaitu peningkatan keberkesanan latihan, peningkatan motivasi dan penglibatan pelajar, peningkatan keselamatan latihan, fleksibiliti pembelajaran yang lebih tinggi, serta penjimatan kos dan masa. Daripada kesemua kesan tersebut, peningkatan keberkesanan latihan merupakan dapatan yang paling konsisten dilaporkan dalam kajian-kajian yang dianalisis. Secara keseluruhannya, dapatan kajian menunjukkan bahawa teknologi VR mempunyai potensi yang besar untuk meningkatkan kualiti latihan kemahiran melalui pengalaman pembelajaran yang lebih imersif, autentik dan selaras dengan keperluan industri. Kajian ini menyumbang kepada pemahaman yang lebih sistematik tentang peranan VR dalam TVET serta menyediakan asas bagi penyelidikan pada masa hadapan dan peluasan penggunaan teknologi imersif dalam latihan kemahiran.

Kata kunci: Realiti Maya (VR), Sorotan Literatur Sistematik (SLR), Pendidikan dan Latihan Teknikal dan Vokasional (TVET), *Head-Mounted Display* (HMD), Latihan Kemahiran, Teknologi Imersif.

ABSTRACT

Although the use of Virtual Reality (VR) technology in Technical and Vocational Education and Training (TVET) has been growing rapidly, a comprehensive synthesis of the technologies employed and their effects on skills training remains limited. Therefore, this study aims to synthesize empirical evidence on the use of VR technology in TVET skills training. A Systematic Literature Review (SLR) was conducted following the PRISMA guidelines by analyzing 21 articles published between 2020 and 2026, retrieved from the Scopus, Web of Science, and Google Scholar databases. Thematic analysis was employed to identify the types of VR technologies used and their effects on TVET skills training. The findings identified five main categories of VR technologies: Head-Mounted Displays

(HMDs), VR software and simulation systems, motion controllers, 360-degree displays, and scenario-based simulations. The analysis further revealed that VR simulators and HMDs were the most dominant technologies used in TVET skills training. In addition, five major effects of VR implementation were identified, namely enhanced training effectiveness, increased student motivation and engagement, improved training safety, greater learning flexibility, and cost and time savings, with training effectiveness being the most consistently reported outcome. Overall, the findings indicate that VR has significant potential to enhance the quality of skills training by providing immersive, authentic, and industry-oriented learning experiences. This study contributes to a more systematic understanding of the role of VR in TVET and provides a foundation for future research and the broader implementation of immersive technologies in skills training.

Keywords: Virtual Reality (VR), Systematic Literature Review (SLR), Technical and Vocational Education and Training (TVET), Head-Mounted Display (HMD), Skills Training, Immersive Technology

INTRODUCTION

The Fourth Industrial Revolution (Industry 4.0) has transformed the global economic and social landscape through the emergence of advanced digital technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), Big Data, robotics, and Virtual Reality (VR). According to Schwab (2016), Industry 4.0 is characterized by the integration of physical, digital, and biological systems, enabling greater efficiency, productivity, and innovation across various sectors. The rapid advancement of digital technologies has significantly influenced the education sector, which is increasingly required to adapt its teaching and learning approaches to meet the demands of modern industries. These changes aim to develop graduates equipped with 21st-century skills, including technological literacy, critical thinking, creativity, and problem-solving abilities. Furthermore, digital technologies have expanded access to education while improving learning delivery and graduate employability (Sousa et al., 2023). Consequently, education and training systems must continuously evolve to align with industrial requirements that increasingly rely on digitalization and automation.

In this context, Technical and Vocational Education and Training (TVET) plays a crucial role in producing a skilled workforce capable of meeting current and future industrial demands. Ramlee et al. (2014) highlighted that TVET serves as a key driver of human capital development and contributes significantly to national economic growth and competitiveness. Through competency-based learning approaches, TVET equips students with the technical knowledge and practical experience required in the labor market. TVET also enhances graduate employability and supports the development of highly skilled workers needed by technology-driven industries (Ishrat et al., 2025). Therefore, TVET institutions are encouraged to adopt innovative teaching and learning approaches to ensure that skills training remains relevant to technological advancements.

One technology that has gained increasing attention in education and skills training is Virtual Reality (VR). VR enables users to experience immersive three-dimensional environments and interact with digital objects in simulated settings that closely resemble real-world situations (Long et al., 2025). Within TVET, VR has emerged as a promising instructional tool capable of bridging the gap between theoretical knowledge and practical application through realistic simulations (Kablitz et al., 2023). By utilizing VR, students can practice technical skills in virtual environments that replicate actual workplaces without being exposed to safety hazards or equipment damage (Lee et al., 2023). As a result, VR is increasingly recognized as an innovative technology with the potential to transform skills training in TVET.

Previous studies have demonstrated that VR can significantly enhance the effectiveness of skills training in TVET. Research conducted by Mulders et al. (2024), Shin et al. (2024), and Mutim (2023) reported that VR improves practical skill acquisition, accelerates learning processes, and enhances student competency development. Through immersive simulations that replicate real working environments, learners are able to understand work procedures more systematically and apply acquired skills more effectively. In addition, VR provides a more realistic and engaging learning experience compared to conventional instructional methods, thereby improving overall training effectiveness.

From the perspective of student motivation and engagement, VR has also shown considerable potential in enhancing learning experiences. Studies by Kolarik et al. (2023), Billert et al. (2022), Doolani et al. (2020), and Mulero et al. (2025) found that VR increases students' interest, concentration, and participation in learning activities through interactive and engaging environments. Immersive learning experiences encourage students to focus more effectively on training tasks while promoting active learning. Furthermore, the incorporation of simulation and gamification elements within VR environments motivates learners to repeatedly engage in training activities until the desired level of competency is achieved.

Another notable advantage of VR is its ability to provide safe and controlled training environments, particularly for high-risk skills training. Studies by Saklangic and Mertoglu (2023), Mondragon et al. (2022), Pedram et al. (2020), and Haminuddin et al. (2024) demonstrated that VR simulations enable learners to undertake training related to fire safety, power substation operations, industrial safety, and technical procedures without exposure to actual hazards. By experiencing realistic workplace scenarios in virtual environments, students can develop confidence, strengthen safety awareness, and improve procedural competencies. Such an approach not only enhances training safety but also reduces costs associated with the use of physical equipment and materials.

In addition, VR supports self-directed learning and distance training opportunities. Research by Pedram et al. (2022), Awang (2023), and Norhanani and Syahrizad (2023) indicated that VR allows students to access training activities anytime and anywhere without the need for physical attendance at training facilities. This flexibility enables learners to practice repeatedly according to their individual learning pace and competency levels. Moreover, VR helps overcome geographical barriers and expands access to skills training, particularly for learners located far from educational institutions or specialized training centers.

Despite its numerous benefits, the implementation of VR in TVET institutions continues to face several challenges. Kolarik et al. (2023) and Mulero et al. (2025) reported that prolonged use of VR devices may cause physical discomfort, including eye strain, dizziness, and difficulties in adapting to new technologies. Furthermore, VR implementation often requires substantial investment in hardware, software, and supporting infrastructure. Factors such as limited technological facilities, varying levels of digital literacy among users, and inadequate institutional support may also affect the effectiveness of VR integration in teaching and learning processes. These challenges suggest that the successful adoption of VR depends not only on the technology itself but also on human, institutional, and environmental factors.

Although interest in VR-based education and skills training has grown considerably in recent years, existing studies remain fragmented across different training fields, technologies, and institutional contexts (Muskhir et al., 2024). Most research has focused on evaluating VR effectiveness within specific settings or on developing VR applications rather than providing a comprehensive synthesis of existing findings. Furthermore, evidence regarding the types of VR technologies employed and their effects on TVET skills training remains scattered across individual studies. This fragmentation makes it difficult for researchers, educators, and policymakers to obtain a comprehensive understanding of VR utilization within TVET. Therefore, there is a need for a systematic literature review that consolidates and synthesizes existing evidence to provide a clearer understanding of the role of VR in TVET skills training.

Accordingly, this study adopts a Systematic Literature Review (SLR) approach to synthesize previous research related to the use of VR technology in TVET skills training. Specifically, the study aims to: (i) identify the VR tools and applications employed in TVET skills training; and (ii) examine the effects of VR implementation on TVET skills training.

The findings of this study are expected to provide a comprehensive overview of VR utilization in TVET and contribute to the advancement of knowledge in technical and vocational education. Furthermore, the results may serve as a valuable reference for researchers, educators, TVET practitioners, and policymakers in developing more effective strategies for implementing VR technologies to enhance skills training quality and prepare TVET graduates for the demands of the Industry 4.0 era.

METHODOLOGY

This study uses a Systematic Literature Review (SLR) approach to collect, evaluate, and synthesize findings from previous studies on the use of VR technology in TVET skills training. This approach involves several main steps designed to ensure the accuracy, reliability, and relevance of the study's findings.

Article Search Strategy

The study process begins with selecting suitable and reliable databases in the fields of education and technology, namely Scopus, Web of Science (WOS), and Google Scholar. This is because Scopus and Web of Science (WOS) are well known for publishing high-impact articles in the academic field, especially among researchers. Meanwhile, Google Scholar is used to broaden the search scope to include a wider range of sources. Therefore, the selection of these three databases aims to ensure that this study obtains materials that are valid, recent, and relevant to the research topic.

Article Selection Criteria

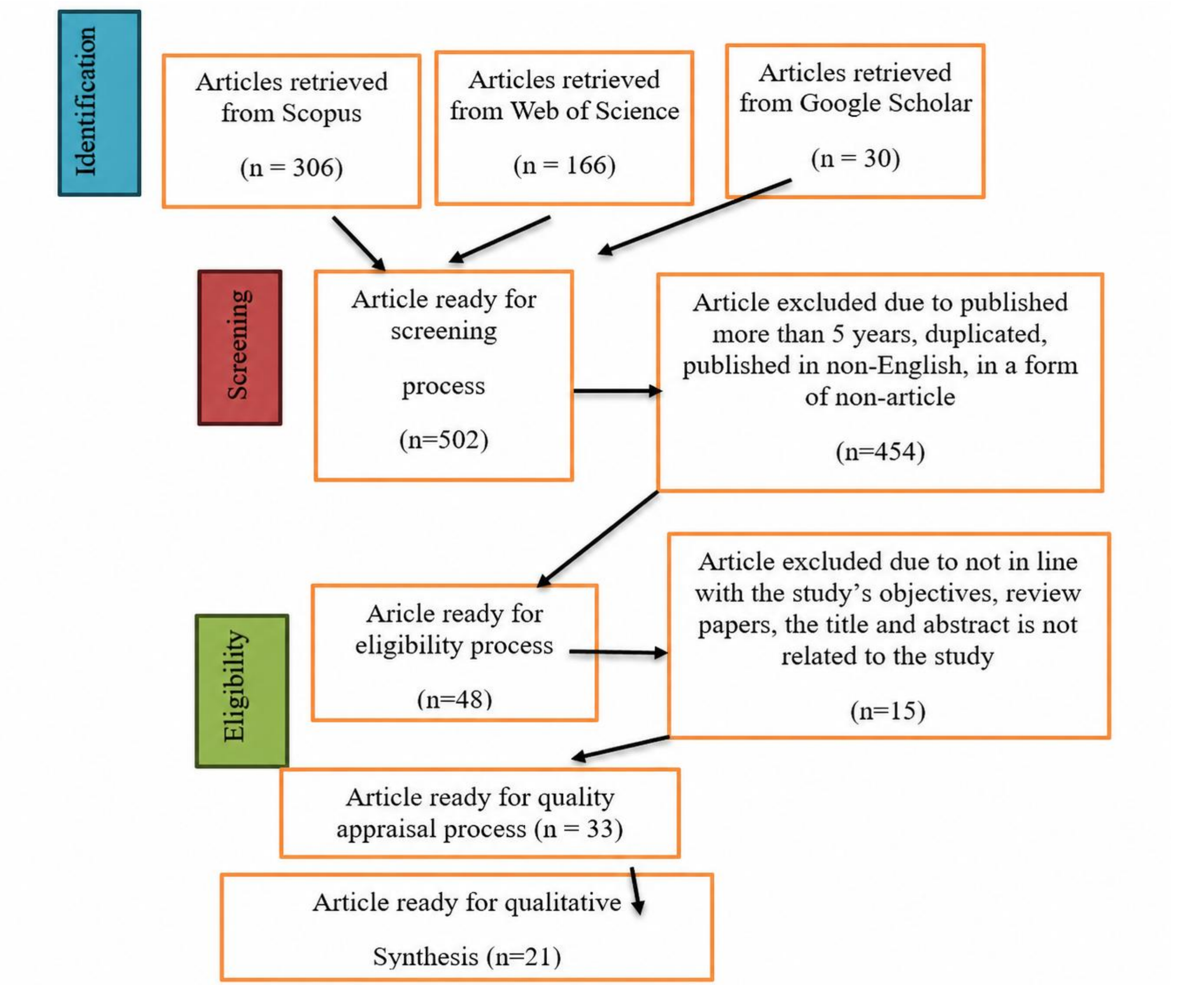
According to Xiao and Watson (2019), a review study that compares a set of literature sources requires a clear, structured process to determine the criteria for article selection. Therefore, this study has set criteria to facilitate an effective literature search. Four selection criteria are used to include or exclude articles: publication year, language, type of reference material, and the field of the journal article, as shown in the table below.

Creteria	Inclusion	Exclusion
Type of Literature	Studies on the use of VR in TVET students' skills training	Studies on VR in video games or medicine unrelated to TVET
Language	Bahasa Melayu, Bahasa Inggeris	Languages other than these two.
Time Frame	Studies published within the last six years (2020 – 2026)	Studies published before the last six years.
Index	Journals indexed in Scopus, Google Scholar, Web of Science	Journals not indexed in recognized databases.
Focus of Study	Studies involving the effectiveness of virtual reality (VR) use in skills training within the context of Technical and Vocational Education and Training (TVET).	Studies involving the effectiveness of virtual reality (VR) use in skills training within the context of Technical and Vocational Education and Training (TVET).

The articles selected for this study are journal articles that discuss the use of VR in TVET skills training during 2020-2026. In addition, only articles in Malay and English are considered, while articles in other languages without translation are excluded. Besides that, the articles are selected only from recognised databases such as Scopus, Web of Science (WOS), and Google Scholar. Studies that do not focus on TVET or skills training are excluded.

Article Selection Process

Figure 1: Prisma flow chart



Identification

In this phase, the article search is conducted using relevant keywords through several main databases. Potential articles are identified through database searches, including Google Scholar, Scopus, and WOS. The search involves keywords in both English and Malay, such as "virtual reality" AND "vocational training", "VR in technical training", *"realiti maya"* AND *"pendidikan kemahiran"*, *"latihan kemahiran"* AND *"teknologi maya",* and "immersive learning" AND "TVET". This search process aims to ensure that the articles obtained are relevant to the research topic.

Screening

This phase involves screening, in which the articles obtained from the initial search are filtered according to strict selection criteria. The main criterion is publication year: selected articles are published between 2020 and 2026 to ensure the information is current and relevant to the present context. The accepted publication type is research journal articles. These articles are written in English or Malay and focus on TVET education and training. In addition, the study's scope must focus on the use of VR in TVET skills training. Articles that do not meet these criteria, such as theses, proceedings, or studies before 2020, are excluded. This screening process helps reduce bias in article selection.

Eligibility

After the articles are screened, the eligibility selection phase is carried out by reading the full articles to ensure their suitability with the research objectives. The researcher evaluates the selected articles by focusing on the alignment with the research objectives and questions, the clarity of the methodology, and the contribution to the study. The selected articles must be related to VR, focusing on the use of tools or applications and their effects on TVET skills training. This final phase selects only articles that fully meet all criteria and includes them in the content analysis. This process ensures that only relevant, high-quality studies are used in this research. Table 1 presents the inclusion and exclusion criteria applied during the article selection process.

Table 1: Criteria for inclusion and exclusion of articles

Criteria	Inclusion	Exclusion
Publication Year	2020-2026	Before 2020
Type of Publication	Research journal articles	Theses, conference proceedings, books, non-empirical studies, literature reviews
Language	English or Bahasa Melayu	Languages other than English and Bahasa Melayu
Scope of Study	Technology and TVET skills training	Studies not related to technology or skills training
access	Open access or available in the university database	Paid articles without full access

Quality Assessment of Articles

The quality assessment of the articles is conducted using the rubric by Mullet et al. (2016), which evaluates seven main components: research objectives, literature review, theoretical or conceptual framework, methodology, findings/results, discussion/conclusion, and reference quality. Each criterion is scored 1-4, yielding a maximum total score of 28 per article.

A total of 21 articles that meet the inclusion criteria are analysed. To ensure that only quality articles are used in this study, each article must achieve at least a score of 14 to meet the minimum quality level for systematic analysis (Margot & Kettler, 2019). Table 2 presents the quality assessment scores of the selected articles based on the evaluation criteria adapted from Mullet et al. (2016).

The assessment shows that all 21 articles meet the required level. Most articles have clear research objectives (scores 3 and 4), especially in identifying the types of VR tools used and evaluating their effects on skills training. The VR tools identified include a head-mounted display (HMD), 360-degree VR video, a VR painting simulator, a VR storytelling system, and VR systems based on learning models such as the four-component instructional design (4C/ID). Some studies also combine VR with game-based technology to increase interaction and student interest in technical learning environments.

Regarding the effects of VR on skills training, articles with high scores (25-28) consistently report significant findings. These include improvement in practical skills, student engagement, learning motivation, and transfer of skills to real-world situations. Articles such as “Virtual Reality in Vocational Training: A Study Demonstrating the Effectiveness of a VR Painting Simulator” (score 28) and “Developing Engineering Students' Capabilities through Game-Based Virtual Reality Technology” (score 25) provide strong evidence on the effectiveness of VR in the TVET context. These studies also use a systematic methodology and clearly report results.

However, some articles with moderate scores (21–23) show weaknesses in their theoretical frameworks and critical discussions. Although these articles still contribute to the general understanding of VR's impact, they tend to describe its effects without strong support from learning theories or training models. This shows the need for more in-depth, theory-based studies to support the effectiveness of VR technology in technical training.

In addition, there are studies that focus on specific groups, such as individuals with special needs or students in rehabilitation programs, for example, in the article “Evaluation of Virtual Reality Job Interview Training (VR-JIT)” (score 20). Although the context is specific, this article provides additional insight into the potential of VR in supporting skills training in real social or work situations, but the discussion and theoretical justification are less strong.

Overall, the quality assessment shows that most high-quality studies meet both objectives of this systematic review: to identify the VR tools used and to evaluate the impact of VR on TVET skills training. These findings provide a strong basis for further thematic analysis and suggest the potential of VR in developing a skilled workforce in the future.

Table 2: Quality assessment of articles

No.	Article	Objective	Literature Review	Theoretical/ Conceptual Framework	Methodology	Findings /Results	Discussion/ Conclusion	References	Score
1	The Intention of Professionals Using Virtual Reality in Training Vocational Skills for Individuals With Disabilities	4	3	4	3	4	3	4	**25**
2	Enhancing the Effectiveness of Virtual Training by Focusing on the Visual-Auditory Characteristics of Trainees and the Virtual Reality Content	3	3	2	3	3	3	4	**21**
3	Virtual Reality in Vocational Training: A Study Demonstrating the Effectiveness of a VR Painting Simulator	4	4	4	4	4	4	4	**28**
4	Effect of Virtual Intervention Technology in Virtual Vocational Training for People with Intellectual Disabilities: Connecting	3	3	3	3	3	3	3	**21**

	Instructor in the Real World and Trainee in the Virtual World								
5	Application of Virtual Reality in Skill Training for Furniture Manufacturing and Woodworking Education	4	3	3	3	4	3	2	**22**
6	Impact of Virtual Reality on Learning Experience Compared to a Paper-Based Approach	3	3	3	3	3	4	3	**22**
7	The Impact of Age and Expertise on Virtual Reality Training Experience and Outcomes in Mine Rescue Training	3	3	3	3	3	3	3	**21**
8	Vocational Training with Microlearning – How Low-Immersive 360-Degree Learning Environments Support Work-Process-Integrated Learning	3	3	3	3	3	3	4	**22**
9	Developing Engineering Students' Capabilities through Game-Based Virtual Reality Technology for Building Utility Inspection	4	4	3	4	4	3	4	**25**
10	Vocational Training in Virtual Reality: A Case Study Using the 4C/ID Model	4	3	4	3	3	3	4	**23**
11	An Immersive Virtual Reality Training Game for Power Substations Evaluated in Terms of Usability and Engagement	4	3	3	3	3	3	4	**23**
12	vIS: An Immersive Virtual Storytelling System for Vocational Training	4	3	2	4	4	3	4	**24**
13	Evaluation of Virtual Reality Job Interview Training (VR-JIT) for	3	3	2	3	3	2	4	**20**

	Returning Citizens in a Prison Setting: An Effectiveness and Implementation Study								
14	Investigating the Process of Mine Rescuers' Safety Training with Immersive Virtual Reality: A Structural Equation Modelling Approach	4	4	4	3	4	4	4	**27**
15	Digital Transformation in Occupational Safety Education: Formulating Components of Virtual Reality in TVET Hospitality Programs Using TPACK Theory	3	3	3	3	3	3	3	**21**
16	Evaluation of the Effectiveness of Virtual Reality-Based Fire Safety Training for Enhancing Occupational Safety Skills	4	3	2	3	4	3	4	**23**
17	*Keberkesanan Kaedah Latihan Kimpalan Melalui Penggunaan Simulator Kimpalan Terhadap Kemahiran Pelatih Institusi TVET*	4	3	4	3	3	3	3	**23**
18	*Potensi Model Dan Algoritma Kecerdasan Buatan Dalam Pendidikan Latihan Teknikal Dan Vokasional (TVET)*	3	3	4	3	3	3	3	**22**
19	*Penyampaian Pengajaran Dan Pembelajaran Dalam Talian Bagi Pembelajaran Berbentuk Kemahiran TVET*	3	4	2	2	3	3	4	**21**
20	Enhancing Robotics Education Through XR Simulation: Insights from the X-	3	4	3	2	4	4	4	**24**

	RAPT Training Framework								
21	The Effectiveness of Virtual Reality (VR) for Construction Skills Training	3	3	4	3	4	3	4	**24**

Data Collection and Data Analysis

The data collection process uses journal articles from three databases: Google Scholar, Scopus, and Web of Science. After eligible articles are identified, this study uses a qualitative content analysis as its main analytical strategy. This method is chosen because it allows the researcher to identify important themes found in each article related to "The Use of Virtual Reality (VR) Technology in TVET Skills Training: A Systematic Literature Review".

Data from the selected articles are then systematically analysed to identify the main themes, including the VR tools used and their effects on TVET skills training. The analysis focuses on five main aspects: head-mounted displays (HMDs), VR software and simulation engines, motion controllers, 360-degree displays, and panoramic images, as well as scenario-based simulations. This analytical approach enables the researcher to gain a holistic understanding of the issues in implementing VR technology in TVET skills training. This study is expected to provide a clear overview by using a systematic methodology.

Content analysis involves a thorough reading of the articles to identify patterns, recurring themes, and relationships among findings across studies. To support the reliability of the analysis, the data are organised into main categories based on the research questions. This allows the researcher to compare and synthesise the information to identify trends, strengths, and gaps in existing research.

Table 3 shows 21 articles, including the authors, year of publication, methodology, findings, research objectives, and field. All selected articles meet the set inclusion and exclusion criteria. According to Kumar (2018), SLR studies also aim to develop a conceptual framework based on previous findings. This is because the framework can be used as a reference and contribute to the literature in future studies. Table 3 below presents the study's findings.

Table 3: Research findings

Title	**Authors /Year**	**Methodology**	**findings**	**VR Technology Tools or Applications Used**	**Impact of VR Use in TVET Training**	**Field**
"The Intention of Professionals Using Virtual Reality in Training Vocational Skills for Individuals With Disabilities"	Lo et al. 2025	Quantitative	TVET students believe VR technology and practical training can help PWDs transfer skills to the real world, and they show high interest in using VR technology in their training.	VR Headset for student with disabilities	Increases professional training efficiency & motivation of students with disabilities	TVET Education
Enhancing the Effectiveness of Virtual Training by Focusing on the Visual-Auditory Characteristics of	Shin et al. 2025	Quantitative	The use of VR with visual and auditory simulation materials effectively improves vocational training performance for	VR headsets such as Meta Quest 2 and motion control devices that allow direct	Able to improve the effectiveness of skills training, facilitate training in a safe place, and overcome time and space constraints.	TVET Education

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Trainees and the Virtual Reality Content			individuals with intellectual disabilities (ID), especially when the intervention is tailored to the participants' sensitivity characteristics.	interaction in the virtual world.		
"Virtual Reality in Vocational Training: A Study Demonstrating the Effectiveness of a VR Painting Simulator"	Mulders et al. 2024	Quantitative	The application of VR in vocational skills training such as vehicle painting is well received, increases motivation and skills mastery, and offers a safer and more effective training environment compared to traditional methods.	3D technology developed using Unity, equipped with an HMD headset (head-mounted visual display) and a controller for the vehicle painting training simulation.	3D technology developed using Unity, equipped with an HMD headset (head-mounted visual display) and a controller for the vehicle painting training simulation.	TVET Education
"Effect of Virtual Intervention Technology in Virtual Vocational Training for People with Intellectual Disabilities: Connecting Instructor in the Real World and Trainee in the Virtual World"	Shin et al. 2024	Qualitative, Quantitative	VR is effective in improving vocational skills and training effectiveness for people with intellectual disabilities. Students who used the VR system compared to conventional methods showed improved performance and the ability to apply these skills in real situations.	VIVE Pro Eye head-mounted display (HMD) and VIVE controllers.	Proven to increase training effectiveness by providing a more realistic and immersive experience, speeding up the learning process, and helping participants apply skills in real situations. Furthermore, VR can provide safe and customizable training according to individual needs, thereby increasing motivation and the effectiveness of vocational training.	Barista
"Application of Virtual Reality in Skill Training for Furniture Manufacturing and Woodworking Education"	Lee, 2023	Qualitative, Quantitative	VR improves students' understanding of group production processes and procedures in furniture manufacturing, enhances their practical skills, and strengthens competence and confidence in facing real production situations in the global furniture industry.	Head display and controllers that provide a realistic experience, as well as additional sensor devices.	Enhances sensory experience and realistic understanding of work procedures, reduces training risks and costs, and helps students understand manufacturing processes and machine operations more effectively.	Furniture Manufacturing

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"Impact of Virtual Reality on Learning Experience Compared to a Paper-Based Approach"	Kolarik et al. 2023	Qualitative, Quantitative	VR provides advantages in terms of improving student mood, motivation, and flow experience. This research shows the great potential of VR as an educational tool capable of adding value to the learning process, especially as technology costs decrease and acceptance increases.	Includes head-mounted displays (HMD), such as Oculus Rift, HTC Vive, and integrated VR tools that allow simulation of practical situations and virtual skills training.	TVET increases motivation, mood, and learning experience, and offers more realistic and interactive training, but there are still challenges such as health and technology adaptation.	Intra logistik
"The Impact of Age and Expertise on Virtual Reality Training Experience and Outcomes in Mine Rescue Training"	Pedram et al. 2022	Quantitative	All participants, regardless of age or experience, gave positive feedback on VR training. Although older participants experienced higher stress and rated VR functionality as less functional, it did not affect the overall effectiveness of the training.	Cylindrical VR Environment is a technology that can display a full stereo 3D VR environment (full 360°).	The use of VR technology in TVET training enhances the learning experience through more realistic and safer training, increases motivation and practical skills, and facilitates access to remote training.	Mining
"Vocational Training with Microlearning - How Low-Immersive 360-Degree Learning Environments Support Work-Process-Integrated Learning"	Billert et al. 2022	Qualitative	Helps workers understand and remember work processes effectively, and provides information for continuous system improvement.	The VR technology tool used is 360-degree images recorded with a 360-degree camera and displayed via computer devices and HMD (head-mounted display).	Increases student interest and engagement, makes training more interesting and realistic, and allows them to learn skills safely and repeatedly.	Machinery manufacturing, fabrication, and automotive industries.
"Developing Engineering Students' Capabilities through Game-Based Virtual Reality Technology for Building Utility Inspection"	Beh et al. 2021	Qualitative, Quantitative	GBVR-based training has the potential to enhance usability, effectiveness, and learning speed in the context of building engineering education.	Technology based on game-based virtual reality (GBVR) integrated with virtual reality (VR) technology.	This platform allows users to conduct building utility inspections interactively in a realistic virtual environment.	Engineering education and industrial training

"Vocational Training in Virtual Reality: A Case Study Using the 4C/ID Model"	Mulders, 2022	Qualitative, Quantitative	The 4C/ID model-based VR simulator works in vehicle painting skills training. It provides a realistic, safe learning experience and helps improve participant competency.	Use of a 4C/ID model-based VR simulator.	Provides a highly realistic and safe learning experience for training participants in the field of vehicle painting. Furthermore, it also helps in increasing participant competency and skills.	TVET Education (vehicle painting field)
"An Immersive Virtual Reality Training Game for Power Substations Evaluated in Terms of Usability and Engagement"	Mondragon et al. 2022	Quantitative	The developed VR system was able to provide a fairly good level of usability and engagement to users, including experienced technicians and students.	Immersive virtual space based on a cave automatic virtual environment (CAVE) system and BIM (Building Information Modelling) Model.	Simulates a real environment for TVET skills training, increases engagement, safety, and learning effectiveness through interactive and realistic experiences.	Engineering
"vis: An Immersive Virtual Storytelling System for Vocational Training"	Doolani et al. 2020	Quantitative	Vis is able to improve participant memory and the system is also rated as very user-friendly and attractive, showing great potential in improving vocational skills training through immersive experiences that combine stories and VR technology.	Vis (Vocational Immersive Storytelling), a virtual reality-based training system that incorporates fictional storytelling elements.	Provides an immersive and interactive training environment, allowing users to learn vocational skills in a more interesting and effective way, and improves long-term memory through visual experiences and virtual world experiences that resemble real situations.	TVET Training (Engineering)
"Enhancing vocational training in corrections: A type 1 hybrid randomized controlled trial protocol for evaluating virtual reality job interview training among returning citizens preparing for community re-entry"	Smith et al. 2020	Quantitative	VR-JIT can improve interview skills and job opportunities and help reduce recidivism, at a more affordable cost compared to traditional programs.	Interactive simulation based on virtual reality. This tool involves job conversation simulations that allow participants to interact with virtual characters.	Increases effectiveness, engagement, and participant confidence through repeated practical training in a real setting. It accelerates learning and helps those who potentially face specific challenges.	Industry Training
Investigating the process of mine rescuers' safety training with immersive virtual reality: A structural equation	Pedram et al. 2020	Quantitative	The effectiveness of VR training is influenced by the perception of realism, co-presence, ease of use, and the level of student engagement.	A large training space that displays 3D images in all directions and Unity 3D software to	Provides an immersive, interactive, and realistic training experience, which allows users to feel as if they are in a real situation, and helps improve skills and	Industrial Safety Training

modelling approach				create realistic simulation environments.	understanding through safe simulation.	
"Digital Transformation in Occupational Safety Education: Formulating Components of Virtual Reality in TVET Hospitality Programs Using TPACK Theory"	Haminuddin et al. 2024	Qualitative, Quantitative	The use of VR has the potential to increase student engagement, learning, and practical skills in kitchen safety aspects in TVET programs.	Head-mounted display devices, sensor equipment, motion controllers, and software such as Unity and Unreal to build interactive and immersive experiences.	The use of VR technology can increase student engagement, facilitate repeated training, accelerate the learning of practical skills, and increase safety awareness in the workplace.	TVET Education (*hospitality*)
"Evaluation of the Effectiveness of Virtual Reality-Based Fire Safety Training for Enhancing Occupational Safety Skills"	Saklangic & Mertoglu, 2023	Quantitative	VR-based training has great potential in improving fire emergency awareness and skills without being influenced by specific demographic factors.	HTC VIVE Helmet and a VR-based simulation system specifically designed for fire safety training and other skills.	Increases learning effectiveness, improves procedural and conceptual skills, enhances safety awareness, and provides a more realistic and interactive training experience without real risk.	TVET Education, safety field, technical training.
Keberkesanan Kaedah Latihan Kimpalan Melalui Penggunaan Simulator Kimpalan Terhadap Kemahiran Pelatih Institusi TVET	Mutim, 2023	Quasi-experiment (Quantitative)	Students who used this technology showed higher effectiveness in mastering welding skills as well as accelerated the learning process and improved their training quality.	The VR technology tools used include a VR welding simulator equipped with Head Mounted Displays (HMD).	Increases training effectiveness and efficiency, accelerates skills mastery, and saves time and costs.	TVET Institute (trainees)
Potensi Model Dan Algoritma Kecerdasan Buatan Dalam Pendidikan Latihan Teknikal Dan Vokasional (TVET)	Awang, 2023	Quantitative	Improves teaching quality, personalizes learning, and enhances the relevance of skills to industry, as well as helps save training costs and time.	The use of AR-VR simulations and virtual models developed through AR and VR applications.	Improves skills, efficiency, and access to remote training, while speeding up and facilitating practical learning processes.	Technical and vocational education
Penyampaian Pengajaran Dan Pembelajaran Dalam Talian Bagi Pembelajaran Berbentuk Kemahiran TVET	Syahrizad & Norha Nani, 2020	Qualitative	The use of technology such as VR can help improve the effectiveness of practical learning, but requires appropriate pedagogical strategies and support.	A computer-generated 3D environment that allows users to interact with an alternate reality.	Supports practical learning, enhances understanding of abstract concepts, visualizes learning materials in 3D form, and increases motivation and active learning.	TVET Education

Enhancing Robotics Education Through XR Simulation: Insights from the X-RAPT Training Framework	Mulero et al., 2025	Qualitative, Quantitative	Students show a clear learning curve, where task completion time becomes shorter even when the difficulty increases. Student engagement and collaboration also improve. VR supports natural interaction and usability, but still has some limitations.	XR platform X-RAPT (VR + PC), VR headset, virtual programming tablet, industrial robot simulation (UR3, ABB IRB120), multi-user system and real-time logging.	Improves procedural skills, collaboration and logical understanding in robotics. Learning is safer (no real risk) and more flexible. However, it requires high-end hardware and may cause user discomfort issues	TVET Education (Robotics / Industrial Training)
The effectiveness of virtual reality (VR) for construction skills training	Thompson et al., 2026	Quantitative	VR is effective in improving competency-based learning. It provides a more immersive learning experience and increases students' focus and engagement. However, there is no significant difference in some aspects of knowledge compared to traditional training.	Head-Mounted Display (HMD), interactive VR systems (height work simulation), virtual environment with realistic animation and objects.	Increases engagement and focus, provides practical learning experience without real risk, helps students develop skills before real situations, but lacks physical interaction elements	TVET Education (construction)

RESEARCH FINDINGS

The findings are synthesised from previous studies published between 2020 and 2026 using a thematic analysis based on the PRISMA framework. The findings show that the use of VR technology has positive effects on TVET skills training, as defined by the study objectives, which focus on the VR tools or applications used and their effects.

What VR Technologies, Tools, or Applications Are Used in TVET Skills Training?

Based on an analysis of 21 journal articles that meet the selection criteria of this study, several VR tools and applications are commonly used in TVET skills training. Through the thematic synthesis process, five main themes are identified: VR technology tools applied in TVET skills training, namely Head-Mounted Display (HMD) as the immersive core, VR software and simulation engines, motion controllers, 360-degree displays and panoramic images, and scenario-based simulations. Table 4 presents the main themes and sub-themes of VR technology tools identified from the selected studies.

Head-Mounted Display (HMD) as Immersive Core

Head-Mounted Display (HMD) is one of the main devices used in Virtual Reality (VR)-based training. Devices such as Oculus Rift and Meta Quest 2 allow users to see the virtual world in three dimensions (3D) in a more realistic and immersive way. Studies by Kolarik et al. (2023) and Saklangic and Mertoglu (2023) show that HMD is widely used in safety training and logistics management, especially to help students understand technical procedures more effectively without being at the actual location. When this technology is applied in TVET skills training for special education students, it shows that HMD is very helpful for students with intellectual disabilities (Shin et al., 2025).

In addition, when HMD is combined with suitable visual and audio elements, it can attract students' attention and help them focus during training. This approach makes HMD not only a viewing tool but also an adaptive and user-friendly learning tool. Overall, HMD not only provides an immersive VR experience but also improves students' understanding, focus, and training effectiveness across various TVET skill areas. Therefore, HMDs are considered an important component in supporting teaching and learning with VR technology in TVET institutions (Kolarik et al., 2023).

VR Software and Simulation Engines

Virtual Reality software developed using engines such as Unity3D and Unreal Engine plays an important role in creating a realistic learning environment that can be adjusted to training needs. Through this software, skills training can be conducted through simulations that mimic real working situations. For example, studies by Mulders et al. (2022, 2024) and Pedram et al. (2020) demonstrate the use of vehicle painting simulator technology using the four-component instructional design (4C/ID) approach, Unity3D and Unreal Engine, which allow students to carry out technical training repeatedly in simulation that reflects real situations. This approach helps students develop skills step by step, aligned with industry needs.

According to Haminuddin et al. (2024), VR technology is also used in kitchen safety training. In the study, VR allows students to practice safety procedures repeatedly without real risk, thereby increasing their understanding and confidence in emergency situations. In addition, in the engineering field, Beh et al. (2021) demonstrate the effectiveness of game-based virtual reality (GBVR) for utility inspection training. Students can explore and conduct inspections in a virtual environment that closely resembles the real world, helping them understand tasks in a more practical, contextual way. Therefore, the use of VR software, together with simulation engines, not only makes training more engaging and safe but also allows it to be tailored to different skill areas. This technology improves learning effectiveness by giving students the opportunity to practice freely and repeatedly in an environment similar to the real workplace (Beh et al., 2021).

Interactive Control Devices Include Motion Controllers

Motion control devices or motion controllers are tools that allow students to interact directly with the virtual environment in VR-based training. These tools make the learning experience more interactive and similar to real working situations. For example, studies by Shin et al. (2024) and Lo et al. (2025) show that using devices such as Vive controllers enables students to perform real movements, including pouring drinks, operating machines, and arranging equipment. This is very useful in service and production fields, where fine motor skills are required.

In addition, a study by Shin et al. (2025) highlights the importance of motion controllers when combined with HMD, especially in TVET education. The combination of these two tools not only makes training more engaging and immersive but also responds to the needs of individuals with different ability levels. Indirectly, the use of motion controllers helps to make the training process more realistic, enjoyable and adaptable to the learning context (Shin et al., 2025). It supports active student involvement and makes the training experience more effective in both cognitive and practical aspects.

360-Degree Displays and Panoramic Images

VR technology that uses a 360-degree display allows students to experience the training environment fully, as if they are at the real location. Studies by Billert et al. (2022) and Pedram et al. (2022) show that panoramic images and 360-degree visuals are effective in helping students understand the structure of work environments, such as mining areas and industrial facilities. Through this method, students can observe work processes, equipment layout and the surrounding environment without being physically present at the location. This makes training more flexible and easier to access, especially for students who have limited access to real training facilities (Pedram et al., 2022).

Therefore, this visual approach is useful at the early stage of training, as it helps students build a contextual understanding before they engage in more complex practical tasks.

Scenario-Based Simulation Systems

The use of VR in the form of scenario-based simulations allows students to experience real working situations in a controlled virtual environment. This approach does not focus solely on technical skills, but also emphasises soft skills such as communication, stress management, and critical decision-making. For example, Smith et al. (2020) introduced the Virtual Reality Job Interview Training (VR-JIT), which is a job interview simulation system that allows students to practice answering questions in a realistic environment using an avatar. Doolani et al. (2020) also used an immersive storytelling approach in the Vocational Immersive Storytelling System (VIS), which helps students understand complex work scenarios through interactive narratives and improves emotional intelligence and empathy.

In addition, a study by Mondragon et al. (2022) shows that power substation training simulations using the Cave Automatic Virtual Environment (CAVE) system and Building Information Modelling (BIM) technology allow technicians and students to interact more deeply with real-world environment models. This training not only improves technical skills but also makes learning more engaging and meaningful. This shows that scenario-based simulations in VR make training more contextual, enrich students' learning experience and prepare them to face various challenges in real working situations.

Table 4: Themes and subthemes of VR technology tools used in tvet skills training

Main Theme	Sub-Theme	Authors
A. VR Technology Used	Head-Mounted Display (HMD)	Shin et al. (2025); Kolarik et al. (2023); Saklangic & Mertoglu (2023)
	VR Software and Simulation Engines	Haminuddin et al. (2024); Mulders et al. (2022,2024); Pedram et al. (2020); Beh et al., (2021)
	Interactive Control Devices	Lo et al. (2025); Shin et al. (2024); Shin et al. (2025)
	360-Degree Display / Panorama Images	Billert et al. (2022); Pedram et al. (2022)
	Scenario-Based Simulations	Smith et al. (2020); Doolani et al. (2020); Mondragon et al. (2022)

Overall Synthesis of VR Utilization in TVET Skills Training

Table 5 indicates that VR software and simulators (57.1%) and Head-Mounted Displays (HMDs) (52.4%) are the most frequently utilized VR technologies in TVET skills training. This pattern suggests that VR implementation in TVET primarily focuses on creating authentic simulation environments and immersive learning experiences to support the development of students' practical skills. In contrast, the use of motion controllers (23.8%) and 360° panoramic displays (9.5%) remains relatively limited, indicating that current VR applications place greater emphasis on visualization and procedural simulations rather than complex physical interactions. Furthermore, the adoption of scenario-based simulations (38.1%) reflects a shift in TVET training towards more contextualized learning experiences that closely resemble real workplace situations. Such an approach enables learners to engage in experiential learning within realistic environments while minimizing the risks associated with actual workplace training. Overall, these findings demonstrate that VR in TVET is evolving as a training medium that emphasizes immersive experiences, training safety, and the authenticity of learning environments.

Table 5. Distribution of VR Technologies in TVET Skills Training

VR Technology	Number of Studies (n = 21)	Percentage (%)	Representative Studies
VR Software / Simulators	12	57.1	Mulders et al. (2022, 2024), Pedram et al. (2020), Beh et al. (2021), Haminuddin et al. (2024)
Head-Mounted Display (HMD)	11	52.4	Shin et al. (2024, 2025), Kolarik et al. (2023), Saklangic & Mertoglu (2023)
Scenario-Based Simulations	8	38.1	Smith et al. (2020), Doolani et al. (2020), Mondragon et al. (2022)
Motion Controller	5	23.8	Shin et al. (2024, 2025), Lee (2023), Haminuddin et al. (2024)
360° Panoramic Displays	2	9.5	Billert et al. (2022), Pedram et al. (2022)

What Are the Effects of Using Virtual Reality (VR) in TVET Skills Training?

In line with the second objective of the study, which is to identify the effects of VR in TVET skills training, the five main themes of VR effects will be analysed in more detail. These include improvement in training effectiveness and efficiency, increased student motivation and engagement, provision of a safe and controlled training environment, support for self-learning and distance learning, and reduction of long-term training cost and time. Table 6 presents the main themes and sub-themes of the effects of VR utilization in TVET skills training identified from the selected studies.

Improving Training Effectiveness and Efficiency

Studies by Mutim (2023) and Lee (2023) show that VR technology can improve the effectiveness and efficiency of training. This is because students can master skills more quickly when using VR than with conventional methods. According to Mutim et al. (2023), VR technology equipped with an HMD can improve the effectiveness of learning to weld and accelerate the learning process. Meanwhile, Shin et al. (2025) state that VR's adaptability to the needs of students with intellectual disabilities improves their overall learning performance. Therefore, VR technology has been proven to improve training effectiveness by providing a more realistic and immersive experience, accelerating learning, and helping students apply skills in real-world settings (Shin et al., 2024).

Improving Student Motivation and Engagement

VR technology can improve student motivation and engagement by providing a more interesting, interactive, and meaningful learning experience. Studies by Kolarik et al. (2023) show that students become more focused and interested when realistic graphics, gamification elements and interactive activities are applied in training. This is because VR can create an immersive environment that encourages students to give full attention to tasks without distractions. This situation not only increases students' interest in learning but also encourages them to explore and repeat the training independently. Although there are challenges, such as technical issues that are more experienced by older students, their level of motivation and engagement remains high because they see the training as having practical value (Pedram et al., 2022). In conclusion, immersive VR learning environments allow students to engage more actively in experience-based training, which helps them better understand technical tasks (Mulero et al., 2025).

Providing a Safe and Controlled Training Environment

One of the main advantages of using VR technology in TVET skills training is its ability to simulate high-risk work environments without involving real danger. Studies by Saklangic and Mertoglu (2023), Haminuddin et al. (2024), and Mondragon et al. (2022) show that VR can provide students with practical training in situations such as fire, industrial accidents and high-voltage electrical operations without exposing them to physical risk. According to Haminuddin et al. (2024), virtual experiences that closely resemble the real world allow students to test and practice safety procedures and emergency responses in a controlled environment. This indirectly helps to build confidence and improve decision-making skills. According to Mondragon et al. (2022), immersive systems such as CAVE combined with BIM models can simulate real power substations, allowing technicians and students to understand complex systems without being at the actual location. Overall, VR can provide a safe, controlled training environment that closely resembles real conditions. This makes it an important tool in high-risk job training and helps students be better prepared and more confident when performing real tasks (Mondragon et al., 2022).

Self-Learning and Distance Training

VR technology also offers advantages in terms of flexibility of time and location, which supports self-learning and distance training. Studies by Pedram et al. (2022) and Awang (2023) show that VR enables students to access training content without being physically present at the training location and to manage their learning time according to their own schedule. This not only improves students' access to learning but also gives them the opportunity to repeat the training independently until they master the skills.

In the context of rural education and unexpected situations such as pandemics, findings from Awang (2023) highlight that the use of VR in a 3D virtual environment can overcome geographical limitations and lack of training facilities. This makes VR a practical solution for expanding access to skills training, especially for communities with limited access to modern education technology. In addition, students' ability to learn at their own pace can foster self-development and internal motivation (Norhanani & Syahrizad, 2023).

Reduction of Long-Term Training Cost and Time

The use of VR technology in TVET training effectively reduces long-term training costs and time. According to Mutim (2023), students who use VR systems can master skills faster without relying on costly, specialised physical training that requires specialised space. This is supported by Thompson et al. (2026) who state that VR enables high-risk skills training at lower cost and in a safer manner, and that it can be repeated without additional cost. According to Mulero et al. (2025), VR enhances efficiency by reducing task completion time, even as the level of difficulty increases. Overall, VR provides a more efficient training solution in terms of time and cost, making it a sustainable approach for current TVET training. Table 5 below shows the themes and sub-themes of the effects of VR in TVET skills training.

Table 6: Themes and subthemes of the impact of VR usage in tvet skills training

Main Theme	Sub-Theme	Authors
B. Impact of VR Usage in TVET Training	Training Effectiveness & Efficiency	Mutim (2023); Lee (2023); Shin et al., 2024
	Motivation and Engagement	Kolarik et al., (2023); Mulero et al., 2025; Pedram et al., (2022)
	Safe Training Environment	Haminuddin et al., (2024); Saklangic & Mertoglu (2023); Mondragon et al., (2022)
	Self-Learning and Distance Training	Awang (2023); Norhanani and Syahrizad, (2023); Pedram et al., (2022)
	Reduction of Long-Term Training Cost and Time	Thompson et al., (2026); Ravichandran & Mahapatra (2023); Mutim (2023)

Overall Synthesis of the Effects of VR Utilization in TVET Skills Training

Table 7 shows that improved training effectiveness is the most frequently reported effect of VR utilization in the literature (81.0%), followed by enhanced student motivation and engagement (66.7%). This pattern suggests that the primary value of VR in TVET skills training extends beyond the adoption of advanced technology; rather, it lies in its ability to improve learning effectiveness through interactive, immersive, and practice-oriented learning experiences. By enabling learners to engage in realistic simulations, VR facilitates deeper understanding and more effective skill acquisition. In addition, nearly half of the reviewed studies reported that VR provides a safer training environment (47.6%), particularly for activities involving high-risk situations such as industrial safety, fire safety, and technical operations. VR-based simulations allow students to practice procedures and develop competencies without exposure to real-world hazards, thereby enhancing both safety awareness and practical preparedness. Although the effects on learning flexibility (38.1%) and cost and time efficiency (33.3%) were reported less frequently, these findings indicate that VR has the potential to support more accessible and sustainable training opportunities over the long term. The ability to access training remotely, repeat learning activities, and reduce dependence on physical resources contributes to greater flexibility and efficiency in skills development. Overall, the current body of literature suggests that the use of VR in TVET not only enhances students' skill acquisition and training outcomes but also supports the transformation of vocational training towards learning environments that are safer, more flexible, and better aligned with industry needs.

Table 7. Effects of VR Utilization in TVET Skills Training

Effect of VR Utilization	Number of Studies (n = 21)	Percentage (%)	Representative Studies
Training Effectiveness	17	81.0	Mutim (2023), Lee (2023), Shin et al. (2024)
Motivation & Engagement	12	66.7	Kolarik et al. (2023), Mulero et al. (2025)
Training Safety	10	47.6	Saklangic & Mertoglu (2023), Mondragon et al. (2022)
Learning Flexibility	8	38.1	Awang (2023), Pedram et al. (2022
Cost and Time Efficiency	7	33.3	Mutim (2023), Thompson et al. (2026)

DISCUSSION

Utilization of VR Technology in TVET Skills Training

The findings indicate that the use of VR technology in TVET skills training is predominantly characterized by the adoption of VR software/simulators (57.1%) and Head-Mounted Displays (HMDs) (52.4%). This trend suggests that VR development in TVET is primarily focused on creating authentic simulation environments and immersive learning experiences rather than relying on passive visualization technologies (AlFajrani et al., 2025). The implementation of VR simulators through platforms such as Unity3D, Unreal Engine, and specialized simulation systems enables students to engage in training activities that closely replicate real workplace environments without depending entirely on physical training facilities, which often involve substantial costs and potential safety risks (Mulders et al., 2022; Beh et al., 2021; Haminuddin et al., 2024).

The dominance of VR simulators across the reviewed studies reflects the growing demand for training approaches that provide safe, flexible, and repeatable practical learning experiences. Mulders et al. (2022) demonstrated that VR simulators developed based on the Four-Component Instructional Design (4C/ID) model support vocational skills training by offering structured and contextualized learning experiences. Similarly, studies by Shin et al. (2024), Shin et al. (2025), and Kolarik et al. (2023) revealed that the use of HMDs enhances the level of immersion and enables learners to interact more realistically with virtual environments. These findings suggest that TVET institutions are increasingly leveraging VR technology as a training medium capable of narrowing the gap between institutional learning and actual industry requirements (AlFajrani et al., 2025). More importantly, this trend reflects a shift in TVET training practices from traditional demonstration- and observation-based approaches towards simulation-based learning environments that allow students to gain practical experience in controlled and authentic settings (Long et al., 2025).

Furthermore, the adoption of scenario-based simulations reported in several studies highlights a transition from demonstration-oriented training to learning experiences that closely mirror real workplace situations. Studies by Doolani et al. (2020), Smith et al. (2020), and Mondragon et al. (2022) found that scenario-based simulations enable learners to apply technical knowledge within realistic work-related contexts. Such an approach not only facilitates the mastery of work procedures but also supports the development of decision-making, problem-solving, and adaptive response skills in complex situations (Andrasi et al., 2025). These findings indicate that the role of VR in TVET has evolved beyond a visualization tool into a medium for comprehensive competency development. This evolution aligns with the fundamental objectives of TVET, which emphasize competency acquisition through learning experiences that closely resemble actual workplace practices (Long et al., 2025).

Despite these advancements, the use of motion controllers and 360-degree panoramic displays remains relatively limited compared to other VR technologies. Studies by Billert et al. (2022) and Pedram et al. (2022) suggest that these technologies are primarily employed for visualization and environmental orientation purposes rather than serving as core components for practical skills development. This trend may be attributed to development costs, additional hardware requirements, and technical challenges associated with implementing such technologies within educational settings. The findings also indicate that current VR research and applications in TVET continue to focus predominantly on immersive simulation development rather than exploring more sophisticated interactive technologies (Kablitz et al., 2023). Moreover, these results imply that TVET institutions currently prioritize technologies that are easier to implement and more cost-effective than those requiring higher levels of interactivity and investment.

Overall, the findings suggest that the development and adoption of VR technologies in TVET are driven by the need to provide more realistic, flexible, and industry-relevant training experiences (Long et al., 2025). The dominance of VR simulators and HMDs reflects the growing tendency among TVET institutions to utilize immersive technologies to strengthen students' skills development through authentic learning experiences. At the same time, more advanced interactive technologies remain at an early stage of adoption and may represent promising directions for future research and innovation in TVET skills training.

Effects of VR Utilization in TVET Skills Training

Based on the overall synthesis presented in Table 7, improved training effectiveness emerged as the most frequently reported effect of VR utilization in the literature (81.0%), followed by enhanced student motivation and engagement (66.7%), training safety (47.6%), learning flexibility (38.1%), and cost and time efficiency (33.3%). These findings indicate that the integration of VR in TVET not only contributes to improved learning outcomes but also supports the development of training environments that are safer, more flexible, and aligned with industry practices (Long et al., 2025; AlFajrani et al., 2025). The findings further suggest that the value of VR extends beyond technological innovation itself, as its primary contribution lies in providing experiential learning opportunities that allow students to actively practice skills within environments that closely resemble real workplace settings (Lee, 2023; Mutim, 2023; Shin et al., 2024).

The enhancement of training effectiveness was consistently reported across the majority of studies included in this review. Studies conducted by Lee (2023), Mutim (2023), Shin et al. (2024), and Thompson et al. (2026) revealed that VR improves learners' understanding of work procedures, task accuracy, and technical skill mastery through repeated practice in controlled virtual environments. Similarly, Mulders et al. (2024) reported that VR simulations provide training experiences that closely replicate actual industrial settings, thereby increasing students' confidence and readiness before engaging in real workplace activities. These findings suggest that VR can address several limitations associated with conventional training approaches, including restricted access to equipment, safety concerns, and high training costs. Furthermore, the ability to repeat training activities according to individual learning needs contributes to improved performance and more effective skill acquisition (Angel-Urdinola et al., 2021). Consequently, VR should not be viewed merely as a content delivery tool but rather as a training medium that facilitates progressive competency development through repeated practice and authentic learning experiences (Long et al., 2025). This capability is particularly important in TVET, where practical skill mastery and compliance with industry competency standards are fundamental objectives.

In terms of student motivation and engagement, the majority of studies indicate that immersive and interactive learning environments significantly enhance learners' interest in training activities. Studies by Kolarik et al. (2023), Mulero et al. (2025), and Shin et al. (2025) reported that VR makes the learning process more engaging and encourages greater participation in practical activities. Learning experiences that closely simulate real-world situations enable students to actively engage in the learning process while providing meaningful opportunities to explore and apply acquired skills (Kablitz et al., 2023). These findings suggest that the immersive characteristics of VR can positively influence student motivation, which in turn contributes to improved learning outcomes. Beyond increasing learner interest, active participation within virtual simulation environments also promotes a more student-centered learning experience. This supports the growing emphasis on active learning approaches within TVET education and skills training (Ravichandran & Mahapatra, 2023).

Apart from enhancing learning effectiveness and student motivation, training safety was identified as another major benefit of VR implementation in TVET. Studies by Saklangic and Mertoglu (2023), Mondragon et al. (2022), and Thompson et al. (2026) demonstrated that VR enables students to undertake training in high-risk environments without being exposed to actual hazards. The use of virtual simulations in industrial safety training, technical operations, and emergency response activities allows learners to gain experience that closely resembles real-world situations before performing tasks in actual workplaces. This capability not only improves training safety but also reduces the risk of equipment damage and lowers operational costs typically associated with physical practical training (AlFajrani et al., 2025). These findings highlight the significant value of VR in high-risk training sectors such as industrial safety, construction, energy, and technical operations, where direct training opportunities are often constrained by safety and cost considerations (Long et al., 2025).

Although learning flexibility and cost and time efficiency were reported less frequently than other categories, both factors demonstrate considerable potential in supporting the implementation of TVET training. Studies by Awang (2023) and Pedram et al. (2022) found that VR enables learners to access training activities at any time and repeat learning experiences according to their individual needs. At the same time, several studies reported that virtual simulations can reduce the consumption of training materials, minimize the need for specialized training facilities, and lower long-term operational costs (Mutim, 2023; Thompson et al., 2026). These findings suggest that VR has the potential to become a more sustainable alternative for supporting skills training over the long term (Leong, 2024).

Despite the predominantly positive findings, several challenges associated with VR implementation were also identified in the literature. These include the high costs of VR system development, the need for specialized hardware, and user discomfort issues such as dizziness, eye strain, and motion sickness following prolonged use (Pedram et al., 2022; Mulders et al., 2024; Thompson et al., 2026). Furthermore, several studies emphasized that the effectiveness of VR depends heavily on training design, simulation quality, and users' readiness to adopt the technology (Haminuddin et al., 2024; Mulero et al., 2025). These findings indicate that successful VR implementation in TVET is influenced not only by the technology itself but also by pedagogical, infrastructural, and organizational factors that support its integration (Leong et al., 2024). Therefore, implementation strategies that focus solely on technology provision are unlikely to achieve optimal outcomes. Instead, effective VR adoption requires comprehensive planning that includes instructor capacity development, adequate infrastructure provision, and continuous institutional support (AlFajrani et al., 2026).

Overall, the findings demonstrate that VR utilization has a positive impact on skills development, learner motivation, and training safety within the TVET context. However, these benefits can only be fully realized when VR implementation is supported by appropriate instructional design, sufficient infrastructure, and systematic implementation strategies. Consequently, VR should be viewed not merely as a technological innovation but as a pedagogical approach with significant potential to enhance the quality and effectiveness of skills training in TVET.

Implications and Recommendations for Future Research

The findings of this study provide several important implications for various stakeholders within the TVET ecosystem, including policymakers, educational institutions, instructors, and researchers. Based on the literature synthesis, VR technology has been shown to enhance training effectiveness, increase student motivation, and provide safer learning environments that closely resemble real workplace situations. However, the successful implementation of VR depends not only on the technology itself but also on pedagogical, organizational, and institutional support factors.

First, greater attention should be given to the professional development of instructors. The findings indicate that the effectiveness of VR-based skills training largely depends on instructors' ability to integrate the technology meaningfully into teaching and learning processes. Therefore, technical proficiency in operating VR systems alone is insufficient without a comprehensive understanding of instructional strategies that are suitable for virtual learning environments (Norhanani and Syahrizad, 2023). Consequently, teacher and lecturer training programs should be strengthened by emphasizing digital pedagogy, simulation-based instructional design, and the development of immersive learning experiences relevant to vocational skills training. Practical and workplace-oriented training initiatives can further enhance instructors' readiness to utilize VR effectively in skills development programs (Krug et al., 2023).

Second, from a policy and institutional management perspective, the findings reveal that although VR offers numerous benefits for skills training, challenges related to system development costs, infrastructure requirements, and equipment maintenance remain significant barriers to implementation. Therefore, comprehensive policies and strategic plans should be developed to support the integration of VR into TVET programs. Such support should include financial investment, digital content development, equipment maintenance, and incentives for institutions adopting VR-based innovations (Saklangic & Mertoglu, 2023). Furthermore, collaboration among educational institutions, industry partners, and relevant agencies should be strengthened to ensure broader access to VR technologies and prevent their concentration within only a limited number of institutions (Mulders et al., 2022).

Third, the synthesis of the reviewed studies highlights the critical role of organizational factors in determining the successful adoption of VR in education and training. Organizational cultures that promote innovation, continuous learning, and openness to change are more likely to facilitate technology acceptance and effective implementation. Studies by Mulero et al. (2025) and Haminuddin et al. (2024) indicate that institutions that encourage experimentation with new ideas and innovative technologies are better positioned to integrate VR successfully into their training practices. Therefore, TVET institutions should cultivate supportive environments that facilitate digital transformation and maximize the benefits of VR for improving the quality of skills training.

With regard to future research, the findings of this SLR indicate that most existing studies focus on evaluating the effectiveness of VR within short-term interventions and specific training contexts. Consequently, action research, quasi-experimental studies, and longitudinal research designs are recommended to examine the long-term effects of VR on learning achievement, skill retention, and competency transfer to actual workplace environments. Such studies would provide stronger empirical evidence regarding the effectiveness of VR in local TVET contexts and contribute to the development of more systematic and evidence-based implementation models (Mulero et al., 2025).

In addition, future research should pay greater attention to students' experiences and perceptions as the primary users of VR technology. Qualitative studies exploring learning experiences, technology-related challenges, acceptance levels, and the long-term influence of VR on skills development could provide deeper insights into the effectiveness of VR in real educational settings (Thakur et al., 2024). Such findings would be valuable in ensuring that VR development and implementation address not only technical requirements but also students' learning needs from a holistic perspective.

Finally, future studies are encouraged to explore the integration of VR with emerging digital technologies such as Artificial Intelligence (AI), learning analytics, and Extended Reality (XR). Although VR has demonstrated considerable potential for enhancing the quality of TVET skills training, research on the integration of these technologies remains limited. Investigating these areas could contribute to the development of more intelligent, adaptive, and responsive learning ecosystems that are better aligned with the evolving demands of future industries.

CONCLUSION

This Systematic Literature Review (SLR) synthesized 21 studies on the use of VR technology in TVET skills training to identify the technologies employed and examine their effects on training and learning processes. The findings reveal that VR software/simulators and Head-Mounted Displays (HMDs) are the most commonly utilized technologies in TVET skills training. This trend indicates that the application of VR in TVET is primarily focused on developing authentic simulation environments and immersive learning experiences that support skills acquisition within real-world workplace contexts.

Furthermore, the review found that VR offers numerous benefits for skills training, particularly in terms of improving training effectiveness, enhancing student motivation and engagement, and increasing training safety. These findings suggest that VR has significant potential as an effective training medium for supporting competency development through interactive, flexible, and industry-oriented learning experiences. Nevertheless, several challenges, including the high costs of system development, infrastructure requirements, and implementation readiness, remain important considerations that must be addressed to ensure the optimal integration of VR within TVET environments.

Overall, this study confirms that VR possesses considerable potential to strengthen the quality of TVET skills training and support technology-driven educational transformation. The findings provide valuable insights for TVET institutions, policymakers, and researchers in developing more systematic strategies for VR implementation, while also contributing to future research on immersive technologies in technical and vocational education and skills training.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Author Contributions

M. Fuad Zamim: Conceptualization, methodology, data collection, formal analysis, and writing – original draft. Nor Hafizah Adnan* & M. Khalid M. Nasir: Supervision, validation, review and editing, and project administration.

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