Metaverse-Integrated Education in TVET: A Bibliometric Analysis

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Abstract The integration of metaverse technologies into education has garnered increasing scholarly interest, particularly in the domain of Technical and Vocational Education and Training (TVET), where immersive, skill-based learning is critical. This study presents a bibliometric analysis to systematically examine the evolution, trends, and thematic structure of research at the intersection of the metaverse and TVET. The analysis focuses on literature retrieved from the Scopus database, covering the period from 2015 to 2025. A total of 165 relevant documents were identified after rigorous screening based on the inclusion and exclusion criteria. The study employed performance analysis and science mapping techniques using VOSviewer to explore publication trends, types of documents, geographical distribution of research output, and key thematic clusters. Findings reveal a growing body of research in recent years, with a marked increase in publications from 2021 onward, reflecting the global surge in interest following the COVID-19 pandemic and the broader adoption of digital technologies. Malaysia and Indonesia emerged as leading contributors to the research landscape, signalling strong regional interest in aligning TVET systems with Industry 4.0 and immersive technology advancements. The document type distribution predominates journal articles and conference papers, underscoring this field's dynamic and evolving nature. Thematic analysis indicates that the core research clusters revolve around virtual reality, augmented reality, gamification, educational technology, and immersive learning systems. These themes highlight an interdisciplinary convergence where digital innovation, pedagogy, and skills training intersect to redefine how technical education is delivered. Despite the potential, the analysis also reveals significant research gaps, particularly in empirical validation, accessibility, infrastructure challenges, and pedagogical integration. This study contributes by mapping the current knowledge structure and research trajectory of metaverse applications in TVET. It offers valuable insights for researchers, educators, and policymakers to understand emerging directions, identify knowledge gaps, and formulate strategies for effectively integrating immersive technologies in vocational education. Future research should expand to multiple databases, conduct longitudinal studies, and explore policy frameworks that ensure equitable and sustainable deployment of metaverse solutions in education.

Keywords: Metaverse, TVET, education, teachers, students, vocational education.

INTRODUCTION

The metaverse concept has emerged as a transformative digital innovation, garnering significant attention across various domains, including technical and vocational education and training (TVET). The metaverse represents an immersive, interactive, and persistent virtual environment where users can engage with digital

content and each other through internet-enabled platforms[1,2]. As immersive technologies continue to evolve, particularly through advances in virtual reality (VR) and augmented reality (AR),

the metaverse is poised to redefine how learning is delivered and experienced in the education sector[3]. In the context of TVET, which emphasizes hands-on and skill-based training, integrating metaverse technologies offers exciting opportunities to replicate real-world scenarios, technical simulations, and industry- relevant experiences in a virtual space. Learners in the metaverse can interact with complex machinery, conduct technical experiments, and simulate workplace environments that may be logistically difficult or costly to replicate in the physical world. This distinguishes the metaverse from traditional VR/AR platforms by incorporating visual immersion and service-oriented and collaborative functionalities that hold educational and social value[4,5]. Significantly, access to the metaverse is not limited to VR or AR devices alone, as the technology is increasingly being optimized for accessibility across various digital interfaces[6].

Integrating the metaverse in education, especially in vocational contexts, can personalize learning experiences, foster student engagement, and support inclusive and adaptive learning environments[7,8]. In TVET, such tools can provide learners safe environments to explore technical tasks and build competencies without the risks typically associated with physical training environments. Widely used platforms like Roblox, with millions of active users, exemplify the scalability and appeal of such immersive systems for educational engagement[9]. With ongoing improvements in hardware usability and digital connectivity, metaverse-based learning in TVET is becoming increasingly feasible and effective[10,11]. Nonetheless, several challenges remain in embedding the metaverse within traditional TVET systems. Issues such as technological accessibility, affordability for institutions and learners, and concerns around data privacy must be addressed to ensure equitable integration[12,13]. Furthermore, the metaverse empowers educators to design emotionally intelligent, socially inclusive, and collaboratively engaging learning environments[14]. These features align with the objectives of TVET to cultivate critical thinking, creativity, and practical problem-solving skills among learners[15,16]. This study's purpose is to systematically explore the scholarly discourse surrounding the use of metaverse technologies in TVET through a bibliometric analysis. By mapping the existing research landscape, this study aims to provide educators, policymakers, and researchers with a comprehensive understanding of the trends, opportunities, and challenges in metaverse-integrated vocational education. More precisely, the study is built on preceding literature, and a bibliometric tool has been used to get a reply to the ensuing research questions below:

RQ1: What is the current trend of research on TVET and the Metaverse?
RO2: What types of research documents are on TVET and the Metaverse?
RQ3: Which nations make substantial contributions to the field of TVET and Metaverse?
RQ4: What are the thematic trends of TVET and the Metaverse?

The remainder of the study is organized into four sections: Section 2 explains the study methodology employed, while Section 3 presents the findings. Section 4 scrutinizes the study's judgments, presents ensuing suggestions, and finishes the research by summarizing its contributions and limits.

METHODS

This study's methodology is predicated on the process of data collection and filtration till the final dataset is robust and prepared for analysis. Beforehand, the topic and scope of the study must be delineated, grounded in the objective of this research, which focuses on all works pertaining to TVET and the Metaverse available in the Scopus database. The Scopus database is selected due to its status as the "largest single abstract and indexing database ever constructed" [17] and the most extensive searchable citation and abstract literature repository[18, 19, 20]. The selection of documents gathered for this study has been created in accordance with the research process outlined by the Prisma Diagram. The statistics were obtained from the Scopus database till 10 April 2025. The following keywords were utilized: “TVET” AND “Metaverse” to ascertain all relevant papers.

Search Strategy

A bibliometric study was performed utilizing the Scopus database as of April 2025. The search query TITLE (“TVET” AND “Metaverse”) was executed in the Scopus database to identify pertinent papers in any language.

Given that titles are the initial elements perceived by a reader[21], we employ the TITLE-ABS- KEY search strategy to guarantee that the identified study publications pertain to TVET education, with a focus on the Metaverse topic, while striving to mitigate the high publication drop-out rate[22]. Figure 1 illustrates our search methodology. A preliminary sample of 165 papers was retrieved from the search.

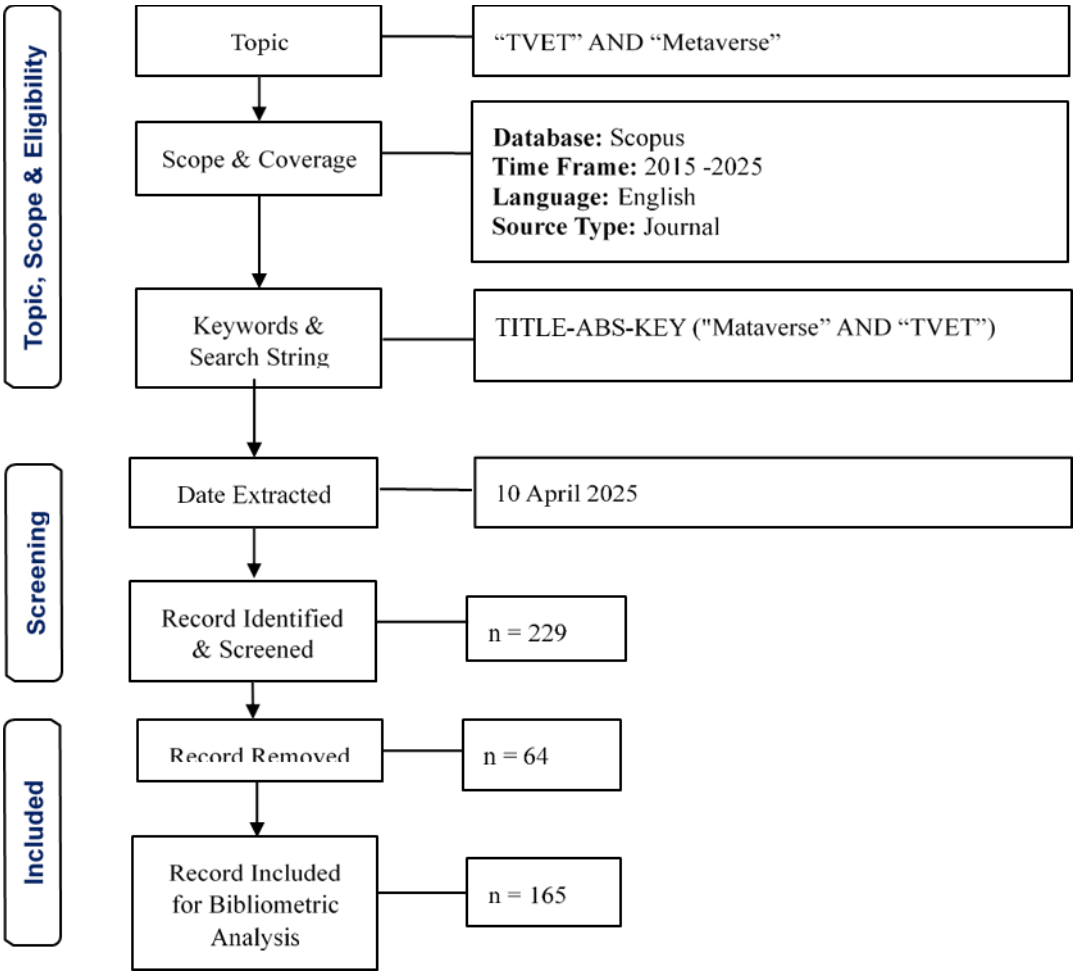

Fig. 1 Prisma Diagram of The Search Strategy

Data Analysis

We conducted a performance analysis in bibliometric studies[22] to elucidate publishing patterns (RQ1), research documentation (RQ2), leading nations in TVET and Metaverse research (RQ3), and topic trends in TVET and Metaverse (RQ4). The frequency and percentage of each publication, along with the requisite graphics, were produced with Microsoft Excel. Furthermore, we augmented our inquiry by conducting a scientific mapping examination utilizing VOSviewer. VOSViewer is a complimentary software program designed to collect citation data, bibliographic information, and keywords to visualize networks of co-authorship and co-citation among writers. The same instrument was also employed to delineate the conceptual framework of TVET and the Metaverse using keyword co-occurrence analysis and bibliographic coupling analysis of papers.

RESULTS

This section outlines our research to establish the status of articles about TVET and the Metaverse in the Scopus database.

Trend in Publication

As shown in the Figure 2 above, TVET and the Metaverse were both research topics over the past several years, and the annual trend in TVET research is rising while that of the Metaverse is falling. The graph shows a relatively small start as few publications occurred between 2012 and 2016, which indicates the small emergence of the Metaverse (and other advanced digitized technologies) into the field of education, and especially into the vocational field. During that time, this term, Metaverse, was just in the early stages of conceptuality, surrounded by virtual reality (VR) and augmented reality (AR) projects with little real application within the educational field[23]. This situation resulted in minimal scholarly attention to the role of TVET in its immersive digital environments, and over time, the majority of the focus was on the traditional e-learning enhancements. Among other things, the 'surge' starts in 2017–2019, when broader technological changes and academic interest in immersive learning environments are starting to show. This corresponds more or less with the emerging Industry 4.0 paradigms, where VR, AR, and digital twins have started to be understood as key means for skills training. Due to the nature of TVET as efficient skill acquisition, it was natural that Metaverse-related concepts began to intersect with research trying to understand how immersive technologies could enhance the training effectiveness, engagement, and real-world applicability. The resulting publications, which are appropriate for this period, showed a steady increase in numbers, primarily due to researchers laying the groundwork for theoretical frameworks and pilot programs, aimed primarily in engineering, healthcare, and technical trades education.

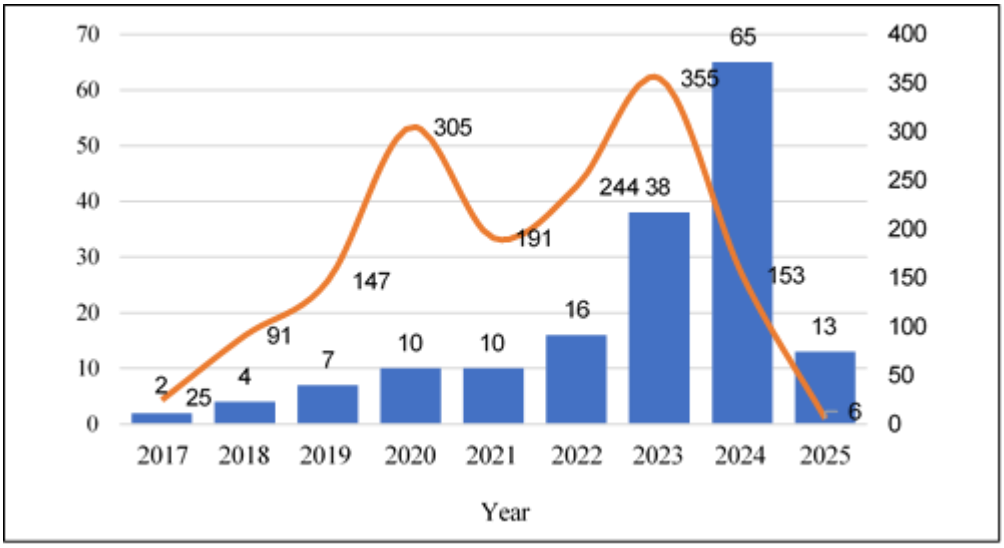

Fig. 2 Trend in the publication of TVET and Metaverse research (2015 - 2025)

Around 2021 to 2022, we have the most significant spike in publications because of the global mass adoption of digital solutions as a result of the COVID 19 pandemic. Remote learning technologies were flexibly adopted during the pandemic and there was a surge in the interest in virtual platforms that could simulate hands on learning experiences, which are important in TVET[24]. The scholarly work on the Metaverse was enhanced by the announcement and promotion of the Metaverse by the leading technology companies including Facebook's rebranding to Meta in late 2021. In light of this external convergence, Metaverse integration in TVET systems has become the focus of research interest, with studies conducted in pedagogical models, technological infrastructures, and the socio-economic implications of Metaverse integration in TVET systems. While the

number grows in 2023 after the peak, it does so slightly and then starts to decline noticeably. Many factors could be responsible for the decline in this case, from the stabilization of urgency related to the pandemic to a more thoughtful debate on the Metaverse's practical challenges[25]: high costs, technical intractability, accessibility limitations. In addition, whereas initial excitement sparked an increase in exploratory studies, later on there may need to be more extensive empirical studies and longitudinal studies to substantiate early claims, consequently slowing down publication volume temporarily. However, the presence of publications suggests that, while the hype cycle has moderated, scholarly attention to optimizing and contextualizing Metaverse applications for TVET is active and growing research.

Publication by Documents

In table 1 presented above is the detailed breakdown of types of documents that were analyzed on the intersection of TVET and the Metaverse. Among the body of literature investigated, 91 papers are considered for contributions, which make up 55.15 % of the total group of publications. This dominance implies that the dissemination of scholarly research on TVET and the Metaverse is dominated by peer reviewed journal article and that a great emphasis has been placed on research base works that contribute squarely to this field. Second largest document represented by 42 contributions (25.45%) correspondingly denote that Metaverse technologies and their application to TVET also found their venue in conferences for sharing the emerging findings and developments possibly because of the rapidly evolving nature of these technologies. 18 documents (10.91%) are dedicated to reviews which indicates that efforts are being made towards synthesizing existing knowledge and compiling complete overviews of the state of research in this field.

Table 1: Annual number of publications and citation matrix

Document Type	**TP**	**%**
Article	91	55.15%
Conference Paper	42	25.45%
Review	18	10.91%
Book Chapter	9	5.45%
Book	2	1.21%
Conference Review	2	1.21%
Editorial	1	0.61%

However, book chapters (9 publications, 5.45%) are less prominent but still noteworthy as they hint that the topic is likewise being embedded in the broader edited volumes and thematic books which might provide additional contextual and interdisciplinary views. The contribution of each 2 documents is 1.21% for books and 1.21% for conference reviews, which suggest a lesser but existing contribution by more elaborate monographs or critical conference evaluations. There is also 1 editorial piece (0.61%, the least amount in the relevance scores) indicating a small amount of editorial commentary or opinion piece about the topic yet. On the whole, the presence of document types in the distribution indicates solid reliance on traditional journal articles for scholarly communication together with frequent dissemination, supported by conferences, and a bit of a presence in reviews, book chapters, and other scholarly formats. Such a distribution is nothing but the emerging maturity and dynamic expansion of research at the crossroad of TVET and Metaverse technologies.

Publication by Countries

Table 2: Publications by Countries

Country	**Continent**	**TP**	**%**
Malaysia	Asia	48	29.09%
Indonesia	Asia	36	21.82%
China	Asia	15	9.09%
India	Asia	9	5.45%

Germany	Europe	8	4.85%
Turkey	Europe	7	4.24%
South Africa	Africa	6	3.64%

The table presented above shows the top 10 countries that contributed to the field of TVET (Technical and Vocational Education and Training) and Metaverse being the highest number (TP) with the allocated percentage. 78.83% of the total output comes from 48 publications from Malaysia. This dominance is due to Malaysia's proactive policies in harnessing Industry 4.0 and digital transformation progress within TVET system. Among the several reasons Malaysia's government heavily emphasised TVET as the driver of economic competitiveness has likely led to extensive interest and research about merging Metaverse like immersive technologies into education spaces. The country of Indonesia is right behind with 36 publications (21.82%) suggesting the pursuit for digital innovations in education in the country despite ongoing national reforms that aim to improve vocational training standards against the evolving industrial sector needs.

Further emphasis is given to Asia's dominance in research related to this domain through the presence of China with 15 publications (9.09%) and India with 9 publications (5.45%). As the program highlight primarily emphasizes the fast development of digital education, AI, and virtual environments in China, as well as the broad coverage of the Chinese TVET system, the research issue focuses on the intersection of education and immersive technology. Likewise, scholarly interests in Metaverse technologies that can close skill gap and enhance employability, especially in technical fields, have arisen as India significantly increases the focus on developing digital skills through "Skill India". Even Taiwan is contributed 6 publications (3.64%) that indicate the nation's strong tendency to innovate in educating through technology according to national digitalization strategy. Germany and Turkey are notable contributors among the others from Europe, with 8 (4.85%) and 7 (4.24%) publications, respectively. Germany's involvement in this Metaverse integration effort brings with it an important reputation for excellence in vocational education and apprenticeship models; namely, as an attempt to future proof traditional educational systems. The national policies of Turkey focusing on modernizing its education system are coinciding with Turkey's increasing interest in educational technology. The above of course also applies to Greece, whose number of 5 publications (3.03%) is indicative of a less mature time when digital realities were increasingly being used to enrich vocational education although it should be added that Greece has wider systemic problems plaguing its educational system. Finally, these European contributions underline that it has been noted that TVET systems have to be innovated in order to meet technological trends in research.

Australia (5 publications, 3.03%) also is notable in Oceania and Africa; and South Africa (6 publications, 3.64%) in Africa. Australia's active research involvement on such national policy follows its overall educational technology strategies and also aligns with the vision of Australia to build up the future workforce for the digitally driven economies. In particular, South Africa's contribution is helpful for the region because it is indicative of a regional willingness to harness new technologies towards closing educational inequalities and skill development gaps. Broadly, the percentage of contributions by these top countries reflect a sphere of global awareness that TVET systems need to adopt Metaverse technologies but not in equal terms of research activities, with Asia leading by a long way, developing scholarship in this growing, inter-disciplinary terrain.

Thematic Analysis

The co-occurrence network visualized through VOSviewer presents a thematic analysis of the literature related to TVET and the Metaverse, revealing key conceptual relationships and clusters within the field. Each node represents a keyword, and the size of the node corresponds to its frequency of occurrence across the analyzed publications. Larger nodes, such as "augmented reality," "virtual reality," "metaverse," and "education," indicate central themes. Lines between nodes (edges) denote co-occurrence relationships, where thicker lines suggest stronger connections. Notably, "augmented reality" emerges as a pivotal theme that bridges multiple clusters, underlining its significance in discussions about integrating immersive technologies within vocational and technical education settings.

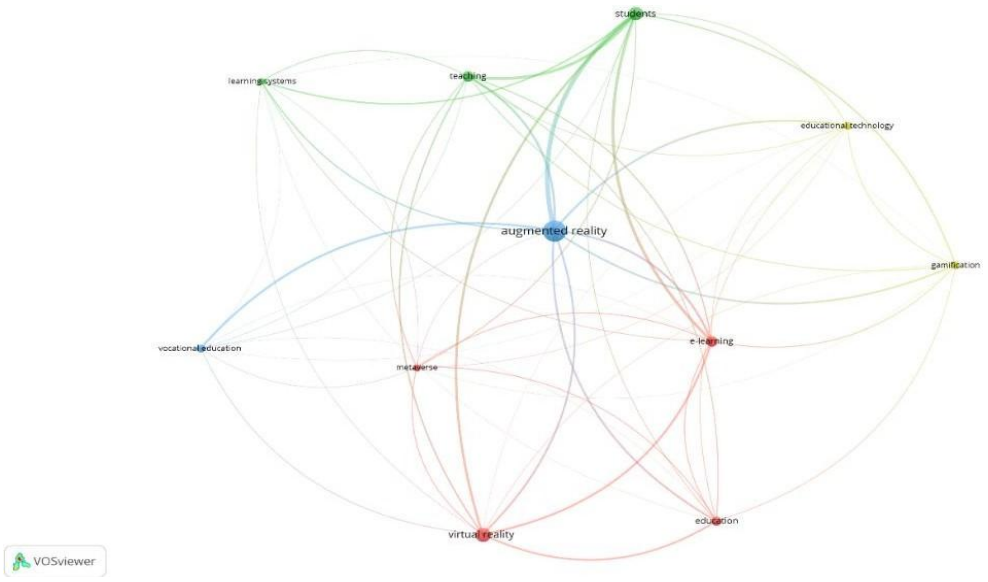

Fig. 3 Thematic Analysis

The network can be interpreted as comprising several clusters differentiated by color, indicating thematic groupings. The green cluster centers around "students," "teaching," "learning systems," and "educational technology," suggesting a strong focus on pedagogical dimensions and the learner-centered aspects of integrating Metaverse and related technologies into TVET. This cluster reflects research interests in how these technologies transform instructional practices, enhance student engagement, and reshape learning environments. The yellow nodes such as "gamification" and "educational technology" further complement this teaching-learning emphasis, pointing towards gamified learning experiences as a sub-theme within the broader educational transformation. The red cluster is predominantly associated with terms like "virtual reality," "e-learning," "education," and "metaverse," emphasizing the technological and educational infrastructure necessary for deploying Metaverse applications in TVET. These connections illustrate an academic focus on building immersive virtual learning environments and understanding how such innovations impact educational delivery. The intersection of "e-learning" and "virtual reality" also highlights a growing convergence between traditional online education methods and newer, more immersive paradigms enabled by the Metaverse, suggesting a redefinition of digital learning ecosystems in vocational education.

Finally, the blue cluster notably includes "vocational education" and "augmented reality," which firmly anchors the discussion within the context of technical and skills-based education. The prominence of "vocational education" linked to "augmented reality" suggests that research is exploring how specific AR applications can enhance practical, hands-on training—a critical component of TVET programs. This thematic proximity highlights the recognition that Metaverse-related technologies are not only theoretical constructs but are actively being positioned to solve practical challenges in skills acquisition and workforce preparation. Overall, the map reflects an interdisciplinary approach where education, technology, and skill development intersect, shaping the evolving discourse on TVET in the Metaverse era.

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