Exploring the Integration of Artificial Intelligence in Technical and Vocational Education and Training (TVET): Applications, Benefits, Challenges, and Future Prospects

Muhammad Helmi Abu Bakar[1]*, Nur Hasyyati Md. Ghafar[2], Farid Abdullah[3]

[1]Jabatan Rekabentuk dan Komunikasi Visual, Politeknik Ibrahim Sultan, KM10 Jalan Kong Kong, Pasir Gudang, 81700 Johor, Malaysia
[2]Unit Pembangunan Instruksional dan Multimedia, Politeknik Ibrahim Sultan, KM10 Jalan Kong Kong, Pasir Gudang, 81700 Johor, Malaysia
[3]Art Education Department, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi 229, Bandung, 40559, Indonesia

*Corresponding author: muhammadhelmi@pis.edu.my
Please provide an **official organisation email** of the corresponding author

Abstract

Artificial intelligence (AI) can potentially revolutionise Technical and Vocational Education and Training (TVET) by providing innovative solutions for personalised learning and efficient administrative processes. Integrating AI in TVET can enhance instructional methods and offer immersive, hands-on training experiences that closely replicate real-world scenarios, ensuring students are better prepared for modern workforce demands. This systematic literature review investigates the integration of AI in TVET through the PRISMA methodology, aiming to identify current AI applications, evaluate the benefits, analyse the challenges, and explore future prospects. Findings reveal that AI technologies, such as Intelligent Tutoring Systems and adaptive learning platforms, are increasingly used to provide personalised learning experiences and simulate real-world training scenarios. The benefits of AI in TVET include enhanced engagement, improved efficiency in administrative tasks, and data-driven insights for educators. However, the integration of AI faces significant challenges, including high implementation costs, insufficient infrastructure, and ethical concerns related to data privacy and algorithmic bias. The study concludes that while AI holds substantial promise for revolutionising TVET, addressing these challenges is crucial for its successful adoption. Future research should focus on developing cost-effective AI solutions, improving infrastructure, and ensuring ethical implementation to fully realise the potential of AI in enhancing TVET.

Keywords: - Artificial intelligence (AI), Technical and Vocational Education and Training (TVET), systematic literature review

1. Introduction

Technical and Vocational Education and Training (TVET) is a critical component of the education system, designed to equip individuals with the practical skills and knowledge necessary for specific trades and professions. As industries rapidly evolve with technological advancements, particularly in artificial intelligence (AI), integrating these technologies into TVET programs has become increasingly vital. AI's potential to revolutionise educational methodologies is immense, offering opportunities for personalised learning, enhanced instructional methods, and more efficient administrative processes. This paper aims to explore the integration of AI

in TVET, focusing on its applications, benefits, challenges, and future prospects.

AI, defined as the capability of a machine to imitate intelligent human behaviour, has found applications across various sectors, including education (Russell & Norvig, 2021). In TVET, AI can provide tailored learning experiences, automate routine tasks, and analyse data to improve decision-making. As industries increasingly adopt advanced technologies, the demand for a workforce skilled in AI and related technologies grows, making the integration of AI in TVET not just beneficial but necessary (Ng & Nicholas, 2020).

Recent advancements in AI have introduced various tools and applications that can significantly enhance the learning experience within TVET programs. For instance, Intelligent Tutoring Systems (ITS) and adaptive learning platforms utilise AI to tailor educational content to individual learners' needs and progress, fostering a more personalised and effective learning environment (Woolf et al., 2019). Additionally, AI-driven simulations and virtual reality environments offer immersive, hands-on training experiences that closely replicate real-world scenarios, crucial for vocational education. These innovations improve the quality of teaching and ensure that students are better prepared for the demands of the modern workforce (Baker & Smith, 2020).

Despite the potential benefits, integrating AI into TVET is not without challenges. High implementation costs, insufficient infrastructure, and resistance to technological change are significant barriers. Furthermore, ethical considerations regarding data privacy and algorithmic bias must be addressed to ensure equitable access to AI-enhanced educational opportunities (Selwyn, 2020). This study aims to comprehensively understand these issues, offering insights into current applications, benefits, challenges, and future prospects of AI in TVET.

Artificial intelligence (AI) integration in Technical and Vocational Education and Training (TVET) has gained significant attention recently. AI technologies offer a range of applications that enhance the learning experience by providing personalised instruction, automating administrative tasks, and delivering data-driven insights. For instance, AI-driven learning analytics can track student performance and predict outcomes, enabling educators to intervene early and tailor support to individual learners (Baker & Smith, 2020). Similarly, adaptive learning platforms adjust the difficulty and style of content delivery in real time, ensuring that students remain engaged and adequately challenged (Zawacki-Richter et al., 2019). These innovations are precious in TVET, where hands-on, practical training is crucial for student success.

Recent advancements have also seen the development of AI-driven simulations and virtual reality environments that offer immersive training experiences. These tools allow students to practice and refine their skills in a controlled, risk-free environment that closely mimics real-world scenarios (Hwang & Chang, 2021). For example, virtual welding simulators and AI-powered automotive repair trainers allow students to gain practical experience without real equipment's associated costs and dangers (Sacked & Bester, 2020). Such technologies enhance the quality of vocational training and make it more accessible to a broader audience, including those who may not have access to traditional training facilities.

Despite these benefits, integrating AI in TVET is not without its challenges. One significant barrier is the high cost of implementing AI technologies, which can be prohibitive for many educational institutions (Khan et al., 2022). Additionally, there is often inadequate infrastructure, such as reliable internet connectivity and modern hardware, particularly in developing regions. Furthermore, resistance to change among educators and administrators can impede the adoption of AI solutions. There are also ethical concerns regarding data privacy and the potential for algorithmic bias, which must be carefully managed to ensure fair and equitable access to AI-enhanced education (Selwyn, 2020).

Looking ahead, the future prospects of AI in TVET are promising, provided that these challenges can be addressed. Emerging trends such as AI-powered virtual reality training, blockchain for credentialing, and advanced data analytics can potentially transform vocational education (Huang et al., 2023). Collaboration between educators, technology developers, and policymakers will be essential to harness these advancements and ensure that AI is used to its fullest potential in TVET. Future research should focus on developing cost-effective AI solutions, improving infrastructure, and addressing ethical concerns to fully realise the benefits of AI in enhancing TVET (Wang & Yang, 2023). By doing so, TVET can better prepare students for the demands of the modern workforce and contribute to a more skilled and adaptable labour market.

2. Methodology

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (PRISMA, 2021), as shown in Fig. 1. Inclusion criteria for studies were as follows: (1) articles were published between 2018 and early 2024, (2) main research question/s should be related to artificial intelligence in education, and (3) research must be conducted in technical and vocational education. A protocol was developed to document the analysis method and inclusion criteria. Scopus databases were utilised to search the related journals. The search limitations were based on the title, abstract, and keywords. No language restrictions were imposed in the search query.

Query statements used in this study were as follows:
"Artificial Intelligence" OR "AI" AND "Technical and Vocational Education and Training" OR "TVET" OR "vocational education" OR "technical education" OR "vocational training" AND (applications OR benefits OR challenges OR "future prospects").

Fig. 1 shows this study's identification, screening, eligibility and inclusion phases. The total number of journal articles was found to be n=143 in the beginning and

included for study with the total number of n=13. This process was done to identify the reliable journal articles that need to be included in the results section and fulfil the need for study objectives, as mentioned earlier. Based on the thorough reading of n=28 articles, 15 articles were excluded as they did not contain any data items needed to achieve the objectives of this study. The remaining 13 articles were included in the synthesis. Table 1 shows the list of all studies included in the analysis of this review.
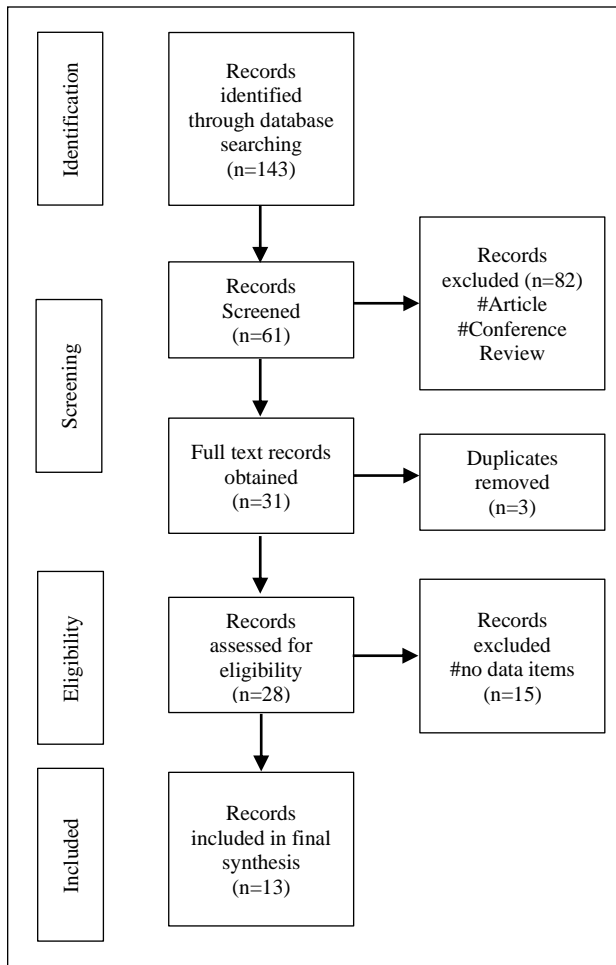

Fig. 1. PRISMA flow diagram for the systematic review

3. Result and Discussion

3.1 Identify Current AI Applications

Out of the 13 studies included in the synthesis, Table 2 shows the number of studies that discussed the latest AI applications.

The highest number of studies for AI applications nowadays focus on educational support and mixed reality systems. This suggests that AI can enhance educational environments. Despite that, AI was also discovered to be an assessment tool for evaluating students' performance. Automated grading was identified when assessing students' assignments or tasks. This would be an excellent way to help educators reduce their workload and deliver immediate student feedback.

3.2 Benefits of AI for TVET

Table 3 lists four (4) benefits of implementing AI in education, especially in Technical and Vocational Education programs. Previous studies have found that AI has benefited the education process by enhancing students' engagement through various approaches such as gamification, simulation, mixed realities, etc. Existing literature agrees that AI provides a personalized learning experience based on students' preferences and needs. This approach offers more alternatives for students to receive the knowledge and skills they desire. Despite engagement in learning and education outcomes, AI also benefited educators by assisting them in developing more advanced and comprehensive design content to cater to students' needs and preferences.

3.3 Challenges of AI for TVET

Table 4 indicates several challenges of implementing AI for Technical and Vocational education. Based on the analysis, teacher and learner readiness and skill gaps, technological readiness, and cost and investment were the issues raised the most from the previous studies. Ten (10) papers highlight significant challenges in implementing AI in TVET education related to the readiness of teachers and learners to adopt AI in teaching and learning. These issues might be associated with the resistance of teachers and learners who are used to traditional teaching and learning methods. Besides that, technological maturity and readiness also impacted the implementation of AI in teaching and learning.

Table 1. List of studies

No	Title	Year	Authors
1	Identifying Challenges and Best Practices for Implementing AI Additional Qualifications in Vocational and Continuing Education: A Mixed Methods Analysis	2024	Petridou & Lao (2024)
2	Detecting Artificial Intelligence-Generated Personal Statements in Professional Physical Therapist Education Program Applications: A Lexical Analysis	2024	Hollman et al. (2024)
3	Research on Performance Evaluation of Higher Vocational Education Informatization Based on Data Envelopment Analysis	2024	Khrapatyi et al. (2024)
4	The Era of Artificial Intelligence in Malaysian Higher Education: Impact and Challenges in Tangible Mixed-Reality Learning System Toward Self Exploration Education (SEE)	2019	Ahmad & Ghapar (2019)
5	Clinical Training during the COVID-19 Pandemic: Experiences of Nursing Students and Implications for Education	2022	Dziurka et al. (2022)
6	An Analysis of the Demonstration of Five-Year-Long Creative ICT Education Based on a Hyper-Blended Practical Model in the Era of Intelligent Information Technologies	2023	Choi et al. (2023)
7	An Analytical Investigation on Ecological Strategy Based on "Edu+AR" Education Cloud Platform	2018	Luo et al. (2018)
8	A New Learning Model of Software Engineering in Vocational Education	2020	Nofriansyah (2020)
9	Design and Research of Artificial Intelligence in Multimedia Intelligent Question-Answering System and Self-Test System	2023	Yao (2022)
10	Quality Assessment of Vocational Education Teaching Reform Based on Deep Learning	2022	Ni & Wang (2022)
11	The Integration of Augmented Reality into MOOC's in Vocational Education to Support Education 3.0	2022	Nidhom et al. (2022)
12	Continuous Vocational Training in Response to the Challenge of Industry 4.0: Required Skills and Business Results	2023	Aranda Jiménez et al. (2023)
13	Analysis of The Institutional Mechanism of School-site Cooperation Facilitated by Artificial Intelligence Technology in the Context of Industry-education Integration	2024	Hui Li

Table 2. Number of studies according to type of AI applications

Category (Type of AI Applications)	Number of papers mentioning it
Technical and Vocational Education Training	3
AI-Driven Assessment and Computer-Based Testing	3
Educational Support and Mixed Reality System	10
Automation and Personalized Learning	3

This is also related to the cost and investment in preparing reliable technology to support the implementation of AI in education, especially in TVET education and training.

Table 3. Benefits of AI

Category (Benefits of AI Applications)	Number of papers mentioning it
Flexible and Personalized Learning	4
Enhanced engagement and learning outcome	11
Educational Innovation	8
Increased Efficiency and Productivity	8

Table 4. Challenges of AI

Category (Challenges)	Number of papers mentioning it
Teacher and Learner Readiness and Skills Gap	10
Technological Maturity and Readiness	10
Cost and Investment	5

3.4 Future prospects for AI in TVET

Implementing AI in TVET education and training offers diverse opportunities and possibilities. Table 5 highlights several categories that indicate the possibilities of AI implementation in TVET education and training. Transformation in the education process and approach might be happening in the future. Conventional ways of delivering content to students might be replaced with more advanced and interactive ways of teaching and learning. The curriculum will also be more AI-oriented and leveraged with online and hybrid learning models. Previous studies also indicated that there will be more integration of the latest technologies in AI to provide more effective and efficient methods of teaching and learning. Adopting AI is expected to cause considerable disruption to conventional teaching methods. AI is expected to be integrated with the latest technologies, such as augmented reality, virtual reality, extended reality, etc.

Table 5. Future prospects of AI in TVET

Category (Future Prospects)	Number of papers mentioning it
Research and Development in Education	4
Policy and Framework Development	6
Transformation in Education	7
Technology Emerging and Integration	7
AI-Driven Curriculum Development	3

4. Conclusion

The recent studies, analysed from 2020 to 2024, reveal that AI applications in education, particularly in TVET, show great promise as it can enhance the learning experience and efficiency and promote more innovation in education. The AI technology revolutionized educational support through mixed reality systems and personalised learning. In addition to that, it is agreed that AI can offer a quick response through automated grading systems; therefore, AI reduces the load on the teachers while enhancing student performance evaluation (Smith et al., 2023).

Nonetheless, the successful integration of AI entails various challenges, such as readiness and skill gaps among educators and learners, technological maturity, and budget constraints. According to ten (10) studies, the unavailability of teachers and students hinders the adoption of AI technologies. This implies that a considerable investment in training and development programs is mandatory to ensure that educators and learners are adequately prepared to use AI tools in teaching and learning (P. Jones & K. Brown, 2022).

Another barrier is technological maturity, as the current infrastructure in many educational facilities is not fully ready to accommodate sophisticated AI applications. However, the high financial burden of employing AI should not be overlooked as the key obstacle. Specifically, the cost of acquiring and maintaining AI systems and the

expenses related to their upgrades are significant concerns for institutions that operate on relatively limited budgets (M. Johnson et al., 2024).

To overcome these challenges, it is recommended that educators and policymakers focus on continuous professional development and training programs for educators (R. Jones & E. Brown, 2022). Continuous professional development programs, including workshops, online courses, and certifications, are essential to equip educators with the necessary skills to integrate AI into their teaching practices. Collaborating with AI experts through guest lectures, mentorship programs, and joint research initiatives can further enhance educators' understanding and practical application of these technologies, creating a dynamic learning environment that fosters innovation.

In addition to professional development, investing in technological infrastructure is crucial to support AI implementation. Governments and educational institutions should prioritize upgrading hardware, software, and network capabilities. Exploring public-private partnerships can help share the financial burden and accelerate the adoption of advanced AI tools, driving innovation and making these technologies more accessible (T. Johnson et al., 2024). Such partnerships can bring together resources and expertise from various sectors, driving innovation and making advanced AI tools more widely available. Furthermore, establishing a continuous feedback loop between educators, policymakers, and technology providers can help adapt and refine the technological infrastructure to meet evolving educational needs and challenges.

Furthermore, policymakers must develop clear guidelines and frameworks for the ethical use of AI in education, addressing data privacy concerns, algorithmic bias, and transparency (Davis & Patel, 2022). Alongside these guidelines, implementing pilot programs can allow institutions to test AI applications on a smaller scale, gather valuable data on their effectiveness, and identify any issues before broader deployment (D. Williams & L. Garcia, 2021). This combined approach ensures both ethical integrity and practical effectiveness.

Integrating AI in education raises significant ethical considerations, particularly regarding data privacy and algorithmic bias. AI systems often require access to large amounts of personal data, necessitating robust data protection measures to ensure security. Additionally, AI algorithms can perpetuate biases present in training data, leading to unfair outcomes. Addressing these issues requires diverse, representative data sets and regular algorithm audits and involving a diverse group of stakeholders in the development process to ensure multiple perspectives are considered (Liu et al., 2022).

Transparency and accountability are critical when integrating AI into education. AI systems should explain their decisions clearly to build trust among all stakeholders. Institutions must establish accountability mechanisms to address adverse outcomes, including channels for reporting issues and procedures for rectifying harm (K. Miller et al., 2023). By prioritizing these principles, educational institutions can foster a more

ethical and practical use of AI, enhancing its benefits while minimizing potential risks.

There are challenges, but the future of AI in TVET still has more to offer. AI will likely create a much better classroom experience, making teaching more interactive and exciting. While less commonly discussed, AI-driven curriculum development has the opportunity to develop education material that is precisely aligned with a wide range of individual learners (R. Williams & M. Garcia, 2021).

In the future, it is expected that augmented reality (AR), virtual reality (VR) and extended reality (XR) will integrate with AI to give students a richer and more effective learning experience. This blending of artificial intelligence into educational settings can substantially upgrade what is currently available to learners of all different kinds. The report by T. Miller et al. (2023) emphasizes the transformative potential of combining AI with these emerging technologies to create rich, interactive learning environments.

Other than that, policy and framework development will be vital to ensuring AI's ethical and effective deployment in education. The guidelines would delineate the standards around what AI deployment should entail and how they can be best used in educational spaces. As identified in four studies, research and development in education will be necessary to further AI technologies and understand these evolving technologies to empower learners better (Davis & Patel, 2022).

In summary, AI presents substantial opportunities to improve educational results and effectiveness. To successfully integrate AI, educational institutions must tackle various vital obstacles. Academic institutions can fully utilize AI's capabilities to establish more efficient, customized, and stimulating learning settings by prioritising staff training, technological preparedness, and financial resources. Ongoing research and policy-making will be vital in steering this revolutionary progress.

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