The Role of Artificial Intelligence in the Industrial Revolution 4.0 Era and Talent Development through Malaysian Technical and Vocational Education and Training (TVET) Programmes

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ABSTRACT

Flexible workplace practices supported by collaborative institutional and industrial partnerships, together with the successful implementation of innovative training programmes, have enabled the bridging of skill gaps through Malaysian Technical and Vocational Education and Training (TVET) programmes. This initiative contributes to lowering Malaysia's unemployment rate by training learners in competencies through real-world industrial settings. TVET fosters the development of globally accepted skilled human capital within formal, non-formal, and informal learning environments, adapting to the digital revolution that is transforming human lifestyles, work practices, and communication. As Malaysia advances from Industrial Revolution 4.0 (IR 4.0) toward Industrial Revolution 5.0 (IR 5.0), skilled workers become critical in accelerating national economic growth. Hence, transforming TVET with national and international credentials is essential to produce a holistic, globally competitive workforce aligned with the National Educational Philosophy. Recognising talent development prepares learners with employability skills, while integration of computer technology enhances innovative teaching and learning. Artificial Intelligence (AI), central to digitalisation in various industries, reshapes global talent development and workforce competencies. Automation and robotics are gradually replacing the human workforce, highlighting the importance of integrating AI into TVET education. This promotes engagement with critical competencies needed for employment and daily routines. Based on this conceptual review paper, this study identifies the roles, strategies, and barriers of AI and talent development within Malaysia's TVET programmes in the IR 4.0 context. It recommends further research to design a framework for integrating AI skills into talent development through TVET.

Keywords: Artificial Intelligence, Industrial Revolution, Talent Development, TVET Programmes, Digital Technology

INTRODUCTION

Malaysia's unemployment rate has dropped significantly due to Technical and Vocational Education and Training (TVET), which enables students to acquire and apply industry-based skills in employment. As the primary approach implemented by the Malaysian government, TVET aims to produce highly qualified human resources by ensuring performance and quality, while fostering a Malaysian community that is evolving, secure, and engaged both socially and economically through well-coordinated transformation initiatives [1]. To achieve this, it is crucial to implement the TVET system effectively by closing the skills gap and delivering flexible workplace practices through collaborations between industry and institutions. Additionally, TVET provides formal, non-formal, and informal learning environments that support talent development across multi-disciplinary capabilities [2].

The Industrial Revolution 4.0 (IR 4.0) highlights how digital revolution and technological advancements are transforming people's lives, workplaces, and communication patterns [3]. Due to globalisation, digital literacy has become increasingly essential for achieving satisfaction in both personal and professional life [4]. Acquiring digital literacy enables individuals to perform tasks that demand technical awareness more effectively. As Malaysia transitions toward Industrial Revolution 5.0 (IR 5.0), the presence of skilled labour becomes essential in accelerating national progress. Currently, Malaysia has only 25% of its workforce

classified as competent, compared to 49% in Singapore, 33% in Taiwan, and 35% in South Korea. To attain IR 4.0 and progress toward IR 5.0, developing competent talent is imperative [5].

TVET became a central focus in the 11th Malaysia Plan as a pathway for continuous education to meet the growing demand for industrial talent. The transformation of TVET, which includes the integration of both national and international credentials, supports the development of diverse talents. This approach aligns with the Malaysian National Educational Philosophy and the broader aim of fostering an economically successful nation with emotionally secure and highly competent individuals [6]. Technical graduates from Higher Educational Institutions (HEIs) are expected to possess four essential attributes: knowledge, skills, abilities, and personality. These dimensions must be regularly assessed to identify gaps, apply corrective measures, and enhance graduate quality to remain globally competitive [7].

Collaboration in the delivery of TVET includes partnerships with the Ministry of Education, Ministry of Higher Education, state governments, private sectors, and other organisations such as the Ministry of Human Resources, Ministry of Youth and Sports, and Ministry of Women, Family and Community Development. These efforts are further supported through engagement with industry players [8]. In the 12th Malaysia Plan, the government intensified its focus on TVET, recognising it as a vital component of the national education system. To better integrate adaptable TVET graduates into the workforce and push Malaysia toward becoming a fully industrialised nation, RM6 billion was allocated for TVET in 2021. The formation of the National TVET Council (MTVET) in December 2020 aimed to enhance cooperation across Malaysia's TVET ecosystem, serving as a bridge between government and major corporations, and improving perceptions of TVET as a viable career path [9].

Despite traditionally receiving less attention than academic-oriented education, the importance of TVET in the educational framework has been recognised [10]. Talent development is necessary to maintain a balance between labour supply and demand. Prior to incorporating digital technology into practical applications, TVET educators and learners must be trained to understand specific hardware and software. This requires thorough planning and strategic direction to encourage digital technology adoption for collective benefit. While educators may possess relevant professional expertise, regulating the talent pipeline to meet both local and global labour market standards remains essential. This includes involving learners in hands-on, experiential learning [11].

TVET curricula should emphasise the use of digital technology in facilitating lifelong learning and preparing learners for digital-era careers. Technology integration into educational programmes requires ongoing upskilling and reskilling. Proposals include using social media for community-based learning and implementing dual systems, supported by innovative digital methods. These shifts in TVET aim to meet evolving industrial demands, address the challenges of IR 4.0, and advance toward IR 5.0 [12]. Prioritising talent development as an element of lifelong learning ensures learners are equipped with transferable skills to succeed professionally and enhance their overall quality of life.

Innovative instructional methods and learning engagements are expected to transform current learners by building the necessary 21st-century competencies. These efforts should focus on both educators and learners integrating digital technology into teaching delivery [13]. Digital education is especially critical at secondary and tertiary levels, providing learners with foundational digital literacy skills required for further education and employment [14]. Effective TVET implementation requires innovative training combined with collaborative efforts between institutions and industries, and flexible workplace strategies. This supports a seamless transition from IR 4.0 to IR 5.0. Malaysian TVET programmes must offer diverse learning environments formal, non-formal, and informal to produce talent with interdisciplinary competencies.

IR 4.0 strongly influences changes in talent behaviour, work practices, and communication. Industry experts can support Malaysia's development during this expansion phase toward IR 5.0. Artificial Intelligence (AI), essential to the IR 4.0 era, helps to understand the connection between humans and technological innovation. Integrating AI into TVET programmes enhances awareness and participation in essential competencies while fostering the development of skilled talent equipped with AI knowledge. This review addresses the roles,

strategies, and barriers related to AI and talent development within Malaysia's TVET programmes in the context of IR 4.0.

METHODOLOGY

This study adopts a conceptual review method, focusing mainly on analyzing secondary data. The review gathers insights from 45 carefully selected sources, which include peer-reviewed journal articles, conference proceedings, seminar presentations, and reliable online materials. materials, specific inclusion and exclusion criteria were applied. Sources were included if they addressed key themes related to Artificial Intelligence (AI), Technical and Vocational Education and Training (TVET), talent development, or the Industrial Revolution 4.0 (IR 4.0), with a focus on the Malaysian context where possible. Only English-language publications dated between 2015 and 2025 were considered to maintain recency. Online content was deemed "trustworthy" if it originated from official government portals, international organizations (e.g., UNESCO, OECD), or recognised academic and policy institutions. Materials such as blogs, informal opinion pieces, and non-peer-reviewed sources were excluded.

In this review, the thematic synthesis was carried out step by step with the aim of keeping the process clear and consistent. At the beginning, all chosen articles were read several times to understand their content deeply and to get a full sense of their context. After that, open coding was done manually by marking important words, repeated ideas, and main concepts that were related to AI, talent development, and how TVET is integrated. These early codes were then grouped into basic themes like "AI in curriculum planning," "implementation barriers," and "digital skills for better employability." In the next phase, more focused coding helped to fine-tune these themes, where similar ideas were merged into broader categories with clearer meaning. To make sure the coding was reliable, another reviewer checked some parts, and both discussed the results until they agreed on the themes' meanings. Even though no formal statistical check like kappa was used, peer discussions added strength to the findings. This back-and-forth method, with teamwork and reflection, helped keep the results closely linked to literature and not influenced by one person's opinion.

Concept Of Artificial Intelligence (Ai)

Although Artificial Intelligence (AI) has been a subject of global academic interest since it was first introduced by John McCarthy in 1956, in Malaysia, its understanding must be rooted in the country's own educational needs and industrial direction. It is not enough to observe AI as a global phenomenon; rather, it is important to consider how it can realistically support Malaysia's national priorities. In particular, the role of AI within Technical and Vocational Education and Training (TVET) deserves focused attention, as this sector is central to workforce development.

The usual classification of AI into Artificial Narrow Intelligence (ANI), Artificial General Intelligence (AGI), and Artificial Super Intelligence (ASI) is often viewed as technical jargon. However, in the Malaysian setting, this framework can serve a practical purpose—it helps to measure where the country currently stands in terms of adoption. At present, it is ANI that is most relevant. Examples such as chatbots and predictive maintenance tools show how AI is being used in simple but effective ways. These forms of AI are already established globally, but their use in Malaysia—especially in TVET—is still developing. In fact, within many Malaysian TVET institutions, the implementation of even basic AI remains at an early stage. While there is growing awareness of AI's potential, actual integration into curriculum and teaching practices is still minimal. This situation suggests a need for stronger efforts to connect AI technologies with educational practice. Without clear planning and support, the gap between potential and practice may continue to widen, limiting the country's ability to prepare its workforce for future demands.[15].

The study of AI does not stay limited to only one field but stretches across many disciplines such as computer science, psychology, philosophy, and language studies. This shows how AI collects knowledge from different areas to build systems that can perform human-like tasks. It includes digital technologies that show cognitive behaviour and programming models made to handle operations which usually require human-level thinking [16].

In the context of TVET, upskilling and reskilling are essential as digital technology becomes a core component of educational settings. Building a professional life is closely linked with acquiring the competencies necessary for labour market entry and improving individual living standards. Therefore, integrating digital technology into instructional and learning practices between educators and learners is vital. As AI continues to draw attention from numerous sectors, the global employment landscape is shifting towards higher skill and competency-based professions. Robotics and automation are progressively replacing human workers in achieving IR 4.0 goals. The growing use of smartphones, laptops, tablets, smart TVs, robotics, and AI is redefining the way people work, further complemented by machine integration. Additionally, innovations such as the Internet of Things, big data, data mining, and automation are significantly shaping employment trends and national economic development by supplying the industrial sector with skilled talent to meet increasing production demands [17].

Learners and vocational educators are actively engaging with diverse digital media during instructional processes. Issues of alienation and passivity have been addressed, although challenges remain regarding mobile learning integration. These include unstable network connections, limited resources, inconsistent digital literacy regulation, insufficient exploration of digital technologies, varying levels of digital mastery among educators and learners, and time constraints [18]. The importance of digital competencies for workforce transformation is undisputed. Therefore, it is crucial to determine effective ways to integrate digital technologies into TVET education, as this integration is central to national development and continuous learning [19].

Adapting teaching and learning approaches to stay current with technological advancements is necessary for achieving IR 4.0 and transitioning into IR 5.0. Although educators and learners are increasingly interested in adopting digital technologies, challenges such as funding limitations, insufficient digital infrastructure, lack of skilled educators, and inadequate resources remain. For successful implementation, educational and TVET institutions require strong government support, relevant policy frameworks, and systematic instructional delivery. Further investigation is needed to better plan and prepare TVET educators and learners for competent digital technology usage [20].

The rapid development of AI continues to reshape global labour markets, directing them towards more specialised and competent roles [21]. Introducing AI education at the foundational secondary level can help learners respond effectively to social transformations and align with labour market needs. This approach also contributes to the achievement of Sustainable Development Goal 4, which emphasises inclusive and equitable quality education and the promotion of lifelong learning opportunities [22].

Role Of Ai in Talent Development

Integrating Artificial Intelligence (AI) into talent development and management requires organisations to inform and obtain consent from prospective employees regarding the evaluation, recording, and use of their personal data by AI systems, ensuring both maximum accuracy and reliability. To maintain accountability, the involvement of third-party assessors in evaluating business applications and software tools can support independent audits, which in turn fosters responsible adoption of AI technologies by developers and organisations, contributing to broader global market integrity [23]. As digital technologies become more pervasive, organisational awareness and internal processes are evolving, consistently seeking to enhance decision-making, forecasting, and operational efficiency [24]; [25]. These improvements largely depend on the integration of AI, which the Society of Human Resource Management (SHRM) has identified as one of its key innovations and a critical component of future human resource management (HRM) practices [26]. In sectors such as the hotel industry, effective application of AI to HR functions requires a clear understanding of specific industry processes and how data analytics can enhance decision-making [27].

AI functionalities significantly influence business operations, particularly in automating complex decision-making tasks such as supply chain management and loan processing. By embedding cognitive abilities into systems, AI enables automation at a more intelligent level. A study by the National Aeronautics and Space Administration (NASA) revealed that up to 86% of human resource tasks could be performed without human involvement when using AI-enhanced HR systems [28]. The decision-making and execution power in such

systems rely predominantly on software algorithms. Research has shown that expert systems powered by AI can emulate the capabilities of human resource professionals in providing appropriate solutions [29]. Consequently, the integration of AI into electronic Human Resource Management (eHRM) systems introduces a range of advantages that organisations can adopt and implement immediately into their practices.

Through AI-powered intellectual analytics, organisations are able to process extensive datasets using machine learning and algorithms, thereby uncovering previously hidden patterns. These insights can be utilised to predict customer buying behaviours, detect fraudulent activities, and craft personalised marketing strategies [30]. Additionally, AI integration facilitates the assessment of relationships between employee engagement and work characteristics more effectively [31]. Cognitive interactions within organisations are also enhanced through the deployment of chatbots and intelligent agents. According to Turing's theory, these tools best represent AI by aggregating and disseminating knowledge from existing databases and interacting with users in natural, human-like ways. Businesses increasingly rely on chatbots to manage growing information demands from prospective applicants, staff, and customers. Similarly, many online retailers employ intelligent agents to assist with consumer decision-making, while corporations are now leveraging chatbots for both internal and external communication functions [32].

In parallel to industries like hospitality, e-recruitment practices benefit from AI technologies by expanding the pool of potential applicants and improving recruitment efficiency. AI-enhanced electronic recruitment systems have the potential to strengthen every phase of the hiring process, from initial screening to competency assessment, thus streamlining talent acquisition strategies.

Strategies In Integrating Ai in Tvet Curricula

AI technologies such as automation, data mining, the Internet of Things (IoT), and virtual reality are now playing a strong role in shaping the national labour market and the economy. Their integration helps in developing a competent workforce within industrial sectors, especially in handling growing production needs. A key ability for fulfilling the aims of Industrial Revolution 4.0 (IR 4.0) is understanding how information technology (IT) connects with industrial systems. AI becomes central in realising IR 4.0, as it not only broadens the field of talent development but also strengthens research inclusion within TVET programmes and offers solutions to challenges linked with technological innovation (33).

To meet these demands, TVET curricula need to be carefully organised according to the pace of technological change, ensuring that educators are well-prepared with the right knowledge and 21st-century skills for effective teaching. The process of education, learning, and evaluation in TVET now covers skills such as complex problem-solving, analytical thinking, creativity, evidence-based decision-making, and teamwork these all have become crucial focus points in today's efforts to reach updated learning standards (34).

In addition, TVET must also place importance on the integration of 21st-century competencies, which are commonly known as TVET 21, by applying instructional methods that follow current pedagogical approaches (35). These approaches should aim to build foundational knowledge as well as essential modern skills such as STEM-related problem-solving and the 4Cs which are critical thinking, communication, collaboration, and creativity. Such competencies should be reflected not only in the system of managing technical and vocational education in Malaysia but also in actual teaching practice, as is being successfully implemented in Thailand's TVET model (35).

TVET must also prioritise the inclusion of 21st-century skills, often referred to as TVET 21, by incorporating instructional strategies based on contemporary pedagogical approaches [36]. This includes imparting foundational knowledge and competencies essential for success in the 21st century, such as STEM-related problem-solving and the 4Cs. These competencies should be embedded not only in the management of technical and vocational education in Malaysia but also reflected in educational practices, as is currently promoted in Thailand's TVET system.

In recent decades, there have been notable advancements in AI and machine learning, beginning with innovations such as support vector machines and extending to today's sophisticated deep learning techniques.

These systems perform exceptionally well across a wide range of complex tasks, including language processing, object recognition in images, and audio signal analysis. Simulations using deep learning highlight AI's disruptive potential, signalling transformative shifts for industries and society at large, with implications extending beyond academia. However, reliance on AI's "black box" predictions such as in medical diagnostics—should be approached cautiously. Critical decisions must still undergo expert human evaluation to avoid adverse outcomes. This is particularly important in fields like autonomous vehicles, where even a single inaccurate prediction could lead to costly or dangerous consequences. As a safeguard, explainable and human-interpretable AI models must be systematically adopted [37].

In this context, organisational innovations along the value chain align with the modular frameworks of IR 4.0 smart factories, driven by a rapid surge in digital operations. These transformations are propelled by the convergence of AI, robotics, cognitive computing, and the Industrial Internet of Things (IoT) [38]. The adoption of IR 4.0 is grounded in eight core technological domains: adaptive robotics, data analytics, machine intelligence, modelling, embedded systems, networking, communication technologies, and cloud computing. Supporting these developments are seven additional components such as cybersecurity, RFID, sensors, integrated business operations, and actuators. These, in turn, rely on foundational technologies like mobile apps, real-time data management, decentralisation, flexibility, and a strong orientation toward customer service.

Barriers In Integrating Ai

To produce skilled human capital, a broad range of technologies must be employed. The digitalisation of work operations has deeply influenced industrial processes and is anticipated to drive comprehensive enhancements in workplace procedures. These changes are also expected to stimulate the emergence of new business models, products, and services, while significantly increasing operational efficiency in line with the goals of Industrial Revolution 4.0 (IR 4.0) [39], [40]. For Malaysia's workforce, sustaining technological advancements and managing the impacts of disruptive technologies particularly the integration of Ai represent critical skill-related challenges. The increasing prevalence of digitalization and highly automated environments is likely to reduce the need for unskilled and semi-skilled labour, which in some cases may become obsolete. As a result, job roles are being redesigned to incorporate IR 4.0 elements, including the restructuring of operations around automation, networking, and digital infrastructure.

At the early stages of IR 4.0, talent gaps may emerge, necessitating a standardised curriculum based on evolving work methods to address the mismatch in skills. Continued learning programmes must place strong emphasis on frequent and targeted training to meet the demands of both current and future human resources. To support a conducive environment for skilled and competent labour, technical processes must be carefully structured to ensure active workforce participation. This involves developing skill-oriented initiatives and reinforcing high-income-targeted strategies led by various Malaysian government stakeholders. Competent human capital should not only be familiar with the terminologies associated with modern work environments such as the Internet of Things (IoT) but also be equipped to resolve technical issues that arise on factory floors or manufacturing lines [41]. The success of this effort depends on the continuous retraining of unskilled workers and the persistent upskilling of trainers.

TVET educators must possess vital attributes including subject matter expertise, the capacity to deliver knowledge effectively, and the willingness to engage in systematic evaluation of curriculum and training. Furthermore, they should continuously demonstrate and enhance their competencies by expanding their industry-relevant knowledge and technical skills [42]. However, several concerns have been raised, including limited self-awareness, outdated pedagogical methods, insufficient practical training, and lack of confidence in performance enhancement especially in the development of social and humanistic competencies among TVET educators [43]. Therefore, while recognising the value of technical expertise alongside technological innovation, it is equally important to overcome key challenges in instructional design, evaluation, program delivery, learner support, and professional development. These areas should be prioritized to strengthen TVET education and ensure alignment with the evolving demands of IR 4.0

DISCUSSION AND IMPLICATION

This study is grounded in the review of 45 secondary sources, encompassing previous research, academic journals, seminar proceedings, conference papers, and online materials. The focus lies on a key competency vital for fulfilling the demands of the Industrial Revolution 4.0 (IR 4.0): the ability to master and engage with digital technologies. Artificial Intelligence (AI) is critical to the implementation of IR 4.0, contributing significantly to infrastructure development, human resource enhancement, and the integration of research into TVET curricula, while also offering sustainable solutions to prevailing systemic barriers. Essential 21st-century skills represented by the 4Cs. Deep learning models clearly show the powerful impact of AI, with the ability to bring major changes not only in academic areas but also in wider economic and social systems. These models demonstrate how AI can go beyond traditional roles and become a strong driver of transformation in various fields. One important trend within the context of Industrial Revolution 4.0 (IR 4.0) is the flexible integration of value chain technologies into modern manufacturing structures. This shift reflects how industries are adapting their production systems to include smart technologies that support efficiency, innovation, and competitiveness.

Within the Malaysian context, maintaining current technological skills while at the same time dealing with challenges brought by fast-changing innovations especially those related to AI has become a serious challenge for national talent development. This issue highlights the struggle to keep up with global trends while ensuring that the local workforce remains equipped with relevant and future-ready competencies. Bridging these skill gaps requires the introduction of a standardised curriculum aligned with employment practices. TVET educators must be proficient in their subject areas, capable of delivering knowledge effectively, and actively engaged in curriculum evaluation and pedagogical development [44]. Overcoming these challenges is necessary not only for talent development within IR 4.0 but also for laying a strong foundation for the progression toward IR 5.0.

Accordingly, TVET institutions are encouraged to reformulate their delivery methods by advancing software-based learning and enhancing network infrastructures to master big data technologies. The discrepancy between the technical skills demanded by IR 4.0 and the current capabilities of the TVET system highlights the need for strategic institutional improvements. Addressing this requires the development of capacities in managing various data types, mastering industrial procedures, fostering collaboration, facilitating effective communication, and driving innovation.

The growing emphasis on innovation across diverse industries has propelled a global transition toward high-skill, competency-based professions largely driven by AI integration. Through strategic and comprehensive educational initiatives, Malaysia seeks to cultivate a highly skilled, well-educated, and emotionally resilient workforce. Continuous reskilling and upskilling are imperative as TVET institutions adopt advanced technologies to boost national productivity [45].

CONCLUSION

The integration of digital technologies into educational environments promotes lifelong learning, enabling educators and learners to explore various instructional preferences within virtual platforms. Incorporating AI extensively enhances the digital learning environment and strengthens collaboration with industry stakeholders. Technological progress has also facilitated the efficient handling and analysis of complex data, which supports informed, long-term decision-making in AI-driven talent development.

In the IR 4.0 era, AI is indispensable for understanding the interplay between technological advancement and human development at both national and global levels. This review has examined the roles, strategies, and barriers associated with AI within the framework of Malaysian TVET programmes. As a foundational effort, it recommends further research aimed at developing a comprehensive framework for the integration of AI competencies into TVET-based talent development initiatives in Malaysia.

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