Enhancing Quality and Employability in Technical and Vocational Education and Training (TVET): Bridging Skill Gaps and Integrating Digital Innovations for Sustainable Development

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ABSTRACT

Technical and Vocational Education and Training (TVET) plays a vital role in workforce development and sustainable economic growth globally. This review examines challenges affecting TVET quality and employability, including skill gaps, curriculum and teaching limitations, institutional barriers, and prevalent perception issues. It highlights the increasing integration of digital innovations such as augmented reality and digital pedagogy, alongside Industry 4.0 competencies, to address these challenges. The review synthesizes strategies for enhancing TVET quality through curriculum reform, industry collaboration, digital pedagogy enhancement, and enrollment interventions. Furthermore, it emphasizes TVET's contribution to sustainable development goals through the embedding of green skills and its positive impact on employment outcomes. The findings underscore the need for coherent policy frameworks aligning TVET with evolving labor markets and sustainability priorities to foster inclusive growth and workforce readiness.

Keywords: Technical and Vocational Education and Training, Employability Skills, Sustainable Development, Curriculum Reform, Industry Collaboration

INTRODUCTION

A. Background and Rationale

Technical and Vocational Education and Training (TVET) plays a pivotal role in workforce development and economic growth worldwide. It serves as a critical avenue for equipping individuals with the practical skills and competencies necessary to meet the demands of increasingly dynamic labor markets. Rudhumbu (2022) highlights that effective implementation of TVET curricula directly influences employability prospects, underlining the sector's instrumental role in shaping the skilled workforce in Botswana. Similarly, Auta and Onwusuru (2022) emphasize that TVET graduates equipped with core employability skills such as communication, teamwork, and problem-solving are essential to meeting the evolving needs of industries like construction, reinforcing the importance of aligning training outcomes with labor market expectations. Ogur (2023) further adds that innovative teaching models such as the Teaching Factory concept significantly enhance practical skill development, fostering innovation and workforce readiness among TVET students.

Globally, there is increasing attention on bridging skill gaps within TVET frameworks while simultaneously integrating sustainability goals. Najib et al. (2022) propose a capability approach framework that addresses the relevance and effectiveness of TVET graduates, particularly emphasizing the construction sector's alignment with national strategic goals. This aligns with findings by Hanafi et al. (2023), who affirm that the incorporation of Sustainable Development Goals (SDGs) into TVET policy and practice is vital for equipping graduates not just for employment but for contributing to broader sustainable economic growth. Mohd Najib et al. (2022) also stress the importance of digital pedagogy in vocational education, advocating for curriculum reforms and teacher training to support the digital competencies necessary for sustainable development.

The rapid technological advancements characterizing the Fourth Industrial Revolution (Industry 4.0) have ushered in new imperatives for TVET systems to evolve. Ngatiman et al. (2023) identify key challenges in embedding Industry 4.0 elements within the Malaysian vocational college curriculum, citing the need for curriculum reviews, infrastructure upgrades, and enhanced teacher readiness to produce a highly skilled workforce aligned with modern industrial demands. Concurrently, Mohammad Yunus and Hapni (2022) underscore the exigency for Malaysian TVET institutions to integrate ICT, automation, and Internet of Things (IoT) technologies into teacher training and curriculum design to remain competitive and responsive to shifting industry landscapes. Such integration not only augments the technical capabilities of students but also fosters creative problem-solving and innovation, which are indispensable in the context of global economic and environmental challenges.

Further advancing this digital transformation, Sani et al. (2023) propose e-learning frameworks tailored for practical TVET courses, highlighting the necessity for specific pedagogical strategies that accommodate the hands-on nature of vocational skills training in an online environment. The adoption of blended learning and Learning Management Systems (LMS) in TVET institutions, as shown by Edeh et al. (2021) and Ahmad et al. (2023), reflects ongoing efforts to enhance accessibility, engagement, and instructional quality, which are critical for sustaining learning outcomes and employability.

B. Research Aim and Objectives

In light of these multifaceted developments and challenges in TVET, this research aims to explore critical issues pertaining to TVET quality and graduates' employability. The study intends to identify and analyze strategic measures that can effectively reduce skills gaps between TVET outputs and industry requirements. Moreover, it seeks to examine the integration of digital pedagogical approaches within TVET systems and assess their impact on teaching and learning efficacy.

Complementing these objectives, the research will also focus on how TVET aligns with sustainable development aspirations, particularly concerning the adoption of green skills and adherence to Sustainable Development Goals. By addressing these aims, the study aspires to provide insights that can guide policy formation, curriculum development, and institutional practices toward an enhanced, sustainable, and digitally empowered TVET landscape.

THEORETICAL AND CONCEPTUAL FOUNDATIONS

A. Employability Skills Frameworks and Their Importance

Employability skills remain a cornerstone in TVET's role in labor market readiness, encompassing a blend of personal qualities, communication, teamwork, leadership, and technical competencies. Auta and Onwusuru (2022) identified key employability skills essential for graduates aiming to succeed in the construction industry, emphasizing personal qualities such as self-discipline and communication, as well as teamwork and technological literacy. Complementing this, Wan Abdullah et al. (2022) found that both experienced and novice TVET trainers viewed communication skills, teamwork, self-discipline, and interpersonal abilities as critical employability skills, highlighting a consensus on skills important for workplace integration.

Alam and Noor (2023) further expanded on predictors of career development among TVET educators, illustrating how personal aspirations, current competencies, and organizational support significantly influence educators' professional growth, which in turn impacts student employability. Despite these acknowledged skills, persistent employability skill gaps remain. Indarta et al. (2021) pointed to inadequacies in TVET graduates' readiness, citing concerns over their competence as human capital in construction technology. Similarly, Maw Maw Tun and Juchelková (2022) emphasized the need for continual development of TVET research and innovation to sustain graduate relevance.

Nazia Azeem and colleagues (2022) investigated the relationship between social support, vocational self-efficacy, and student interest in TVET programs, revealing surprisingly weak correlations, which suggests that

employability skill perception and motivation among students require more nuanced approaches. The awareness of skill mismatches and the industry's perception of graduates informs the continuing need to refine TVET curricula and training approaches.

B. Digital Pedagogy and Technology Integration in TVET

The integration of technology in TVET teaching is essential to cope with the demands of the digital era, especially as TVET increasingly incorporates Industry 4.0 elements. Mohammad Hafiz Salleh et al. (2022) examined factors influencing TVET teachers' Technological Pedagogical Content Knowledge (TPACK) competency, a framework vital for effective teaching in digital environments. They highlighted mentoring and school environment as significant contributors to TPACK development, underscoring the institutional role in supporting technological integration.

Gbadegbe et al. (2023) applied the TPACK model to art teachers in TVET, revealing a strong relationship between technological knowledge and the extent of technology use in classrooms, which is central to enhancing quality teaching and learning across disciplines. Addressing challenges in digital pedagogy, Mohamad Yunus and Hapni (2022) analyzed technology integration among TVET lecturers in Sarawak, reporting predominant technological knowledge but limited holistic TPACK proficiency, signaling a need for professional development that aligns pedagogical and content knowledge with technology.

Frameworks for digital learning have evolved to support practical skill acquisition effectively. Sani et al. (2023) developed an e-learning framework for TVET practical skills courses, integrating augmented reality and community of inquiry principles to enhance teaching and learning interactions. Similarly, Abdul Hamid et al. (2024) found positive instructor perceptions towards augmented reality applications for skill training, despite challenges such as acceptance and institutional policy constraints, indicating AR’s potential to transform TVET pedagogies.

Razak et al. (2023) conceptualized a case-based simulation framework within electrical technology, supporting engagement and development of critical soft skills like problem-solving, bridging pedagogy and practical workplace scenarios. These innovations demonstrate digital pedagogy's central role in equipping TVET students with competencies aligned with modern industry requirements.

C. Sustainable Development and TVET

TVET’s contribution to sustainable development is progressively recognized, especially regarding its alignment with the United Nations Sustainable Development Goals (SDGs) such as decent work and economic growth. Hanafi et al. (2023) discussed how integrating TVET and skills development can reinforce SDG targets, highlighting ongoing efforts by international and multilateral organizations to promote inclusive and lifelong learning pathways.

Alam and Sharmin (2023) supported these findings through their examination of Japanese language skills programs in Bangladesh TVET, demonstrating how specialized skills development fosters employability both locally and in international labor markets, thus contributing to economic growth and social sustainability.

Curriculum transformation to embed environmental responsibility is a critical part of TVET's sustainable development role. Lai Chee Sern et al. (2021) identified specific green skills—such as pollution control, energy-saving, and recycling—to be integrated into polytechnic engineering curricula, responding to emerging green industry demands. Such curricular reforms represent proactive responses aligning training provisions with global sustainability trends.

The conceptual and practical linkages among employability skills, digital pedagogy, and sustainable development challenge TVET institutions to continuously adapt. This adaptation involves embedding holistic competencies suited for evolving economic, technological, and environmental contexts, ensuring that graduates not only secure employment but also contribute meaningfully to sustainable development goals.

D. Skill Gaps and Mismatches

One of the most prominent challenges facing Technical and Vocational Education and Training (TVET) systems globally is the persistent skill gap between graduates' competencies and the demands of the industry. This discrepancy affects the employability of TVET graduates, limiting their integration into labor markets. Auta and Onwusuru (2022) found in the construction industry context that TVET graduates lack essential employability skills, including teamwork, communication, leadership, and technological proficiency. This gap arises because curricula and training often fail to align with dynamic industry requirements, leading to graduates insufficiently prepared for workplace challenges. Similarly, Rodzalan et al. (2022) report discrepancies in both soft and hard skills within the electrical and electronic industries in Malaysia, underscoring the widespread nature of skills mismatches. Badawi and Drăgoicea (2023) further highlight the skills gap in TVET education, emphasizing the need for innovative pedagogical practices that can bridge these deficiencies.

Closely related is the issue of a demand-supply mismatch between TVET program offerings and labor market needs. Ibrahim and Nashir (2022) identify three types of mismatch in Malaysian polytechnic TVET programs: between industry demand and program supply, student demand and program supply, and institutional readiness with program supply. Their study calls for realignment of curricula to reflect stakeholder needs to enhance graduate employability. Roslan et al. (2023) stress challenges in implementing Learning Management Systems (LMS) in TVET institutions, which are critical in delivering updated curricula and flexible learning approaches addressing market demands. Such mismatches hinder the responsiveness of TVET systems to competitiveness and labor requirements.

E. Teaching and Curriculum Implementation Challenges

The predominance of traditional lecturer-centered teaching methods further restricts TVET quality and graduate readiness. Rudhumbu (2022) identifies lecturer-centered strategies as a key barrier to effective curriculum implementation, blocking active and practical learning. Complementing this, Mesuwini and Mokoena (2023) examine Work-Integrated Learning (WIL) for TVET lecturers in South Africa and uncover limited industry engagement, lack of supervision, and restricted hands-on use of advanced machinery. These factors reduce the lecturers' ability to offer current, practical skills training, thereby widening the divide between graduate capabilities and workplace expectations.

Another significant teaching-related challenge is the limited readiness and capacity among TVET lecturers to adopt and integrate digital and Industry 4.0 (IR4.0) technologies in teaching. Ngatiman et al. (2023) in Malaysia found challenges including curriculum revision, insufficient educator preparedness, inadequate infrastructure, and poor institutional engagement with industry—all obstructing the embedding of IR4.0 elements within vocational college curricula. Mohammad Hafiz Salleh et al. (2022) similarly report varied competencies among TVET teachers in digital pedagogical knowledge (TPACK competencies), with mentoring and supportive school environments playing major roles in competency development. These findings suggest systemic gaps in preparing TVET educators for evolving technological demands.

Perception challenges and stigma attached to TVET education significantly impact student enrollment and motivation. Shaari et al. (2024) reveal that societal misconceptions and "3D illusions" (dirty, dangerous, and difficult) contribute to low valuation of TVET by students in Malaysia, negatively influencing their career choices. Omar and Desa (2023) observed that despite labor market demand, TVET remains an unpopular option due to limited awareness and negative attitudes. Azeem et al. (2022) found that secondary students in Pakistan exhibited poor interest in TVET programs across affective, cognitive, and conative dimensions, with demographic disparities influencing interest levels. Such perceptions not only affect enrollment but also generate gender and geographic inequalities in TVET participation.

F. Synthesis of Patterns, Contradictions, and Explanatory Factors

A cross-analysis of the reviewed literature reveals several recurring patterns across diverse contexts. Persistent skill gaps are repeatedly highlighted across industries—including construction and electrical and electronic

sectors. For instance, Auta and Onwusuru (2022), Rodzalan et al. (2022), and Badawi and Drăgoicea (2023) all indicate ongoing misalignment between curricula and labor market needs. At the same time, widespread acknowledgement of the importance of digital pedagogy contrasts with uneven institutional readiness and variable teacher competencies, as noted by Mohammad Hafiz Salleh et al. (2022), Ngatiman et al. (2023), and Mohamad Yunus and Hapni (2022), demonstrating systemic challenges in technology integration.

Contradictions also emerge across studies and regions. For example, while Abdul Hamid et al. (2024), Razali et al. (2022), and Razak et al. (2023) report positive acceptance of blended learning, augmented reality, or digital tools, Mohammad Hafiz Salleh et al. (2022) and Mohamad Yunus and Hapni (2022) reveal low technological self-efficacy and limited holistic TPACK mastery among lecturers. Similarly, findings on TVET perceptions vary: Shaari et al. (2024) report improving student interest through behavioral interventions, whereas Sunny and Ismail (2023), Azeem et al. (2022), and Omar and Desa (2023) highlight deep-rooted stigma and low awareness.

Several explanatory factors help account for these inconsistencies. Institutional governance, funding availability, and the strength of industry partnerships play central roles in influencing curriculum relevance and pedagogical effectiveness, as emphasized by Subri et al. (2022), Norazlinda et al. (2023), and Mutebi and Ferej (2023). External contextual variables—including national development priorities, sector-specific demands, teacher training pathways, and urban–rural differences—also shape learning outcomes and system performance, according to Hanafi et al. (2023) and Ibrahim and Nashir (2022).

Overall, this synthesis highlights that TVET challenges and opportunities are deeply context-dependent, reinforcing the need for integrated, multi-level reforms that align curriculum, technology, institutional governance, and labor market engagement.

G. Institutional and Managerial Barriers

Institutional leadership and governance challenges constitute significant barriers to TVET quality assurance and collaboration with industry. Abdullah et al. (2021) established a leadership model for Malaysian TVET institutions highlighting the necessity for high-impact leadership to navigate global developments and produce competitive graduates. However, Norazlinda et al. (2023) identified barriers faced by TVET institution directors in managing industry collaborations, including a lack of managerial computer skills, experience in strategic planning, and ineffective relationship management. These managerial deficits obstruct the potential benefits of partnerships with industry for curriculum relevance and resource sharing.

Quality assurance governance frameworks in many developing contexts remain fragmented and outdated. Mutebi and Ferej (2023) reviewed Uganda's TVET quality assurance practices and uncovered loopholes such as governance scattered across multiple bodies, absence of comprehensive regulatory frameworks, and lack of policy implementation action plans. Similar results are echoed in Malaysia by Marzuki et al. (2023), who emphasize the emerging necessity for national digital pedagogy policies to align with evolving teaching and ICT demands. Additionally, funding constraints and governance issues frequently complicate effective quality assurance and institutional sustainability, undermining the capacity of TVET providers to modernize and expand.

In summary, the challenges in TVET quality and employability are multi-faceted, involving skill mismatches, curricular and pedagogical limitations, societal perception issues, and institutional governance hurdles. Addressing these challenges requires comprehensive reforms and strategic alignment among educators, policymakers, industries, and communities to fulfill TVET’s potential as a catalyst for workforce development and sustainable economic growth.

H. Conceptual Framework (TVET Capability Approach)

To unify the diverse themes identified in this review—employability, digital pedagogy, sustainability, and institutional governance—this study adopts the TVET Capability Approach Framework (TVET-CAF) proposed by Najib et al. (2022). Rooted in Sen’s capability theory, TVET-CAF conceptualizes TVET’s role as

expanding learners' "capabilities," or their real opportunities to achieve valued outcomes such as decent work, digital adaptability, and participation in sustainable economic development. This framework links input factors (curriculum design, pedagogical strategies, digital infrastructure, and industry engagement), conversion factors (institutional leadership, teacher competencies, student motivations, and societal perceptions), and capability outcomes (employability, green skills, lifelong learning readiness).

Applying TVET-CAF provides an analytical structure that integrates findings across disparate domains. Ngatiman et al. (2023) and Mohammad Hafiz Salleh et al. (2022) highlight that curriculum misalignment and digital readiness gaps hinder learners' capability expansion, whereas Subri et al. (2022) and Abdullah et al. (2021) emphasize that supportive governance and strong industry collaboration improve the conversion of competencies into meaningful employment. Similarly, Lai Chee Sern et al. (2021) and Hanafi et al. (2023) argue that embedding green and sustainable skills expands learners' potential to contribute to SDG-related outcomes. Framing this review through TVET-CAF thus strengthens analytical coherence and underscores the interconnectedness of pedagogical, technological, institutional, and economic factors that shape TVET quality and employability.

STRATEGIES FOR ENHANCING QUALITY AND EMPLOYABILITY IN TVET

A. Adoption of Digital Learning and Blended Models

The adoption of digital learning and blended education models in TVET institutions has gained remarkable attention, especially following challenges such as the COVID-19 pandemic which necessitated remote learning solutions. Sani et al. (2023) developed a TVET e-learning framework specifically for practical skills courses, which traditionally depend on hands-on experience, making the digital shift complex. Their study applied the Community of Inquiry model and the Malaysian Qualifications Framework, incorporating augmented reality to bridge the gap between practical skills and online delivery. Experts in their study agreed on the essential framework elements, which facilitate learner engagement, foster creativity, and enhance instructor-student communication. This framework supports the effective online conduction of practical courses while maintaining the rigor required in TVET.

Complementing this, Razali et al. (2022) documented the challenges and adaptations that TVET institutions underwent to implement blended learning during the COVID-19 pandemic. Their research showed that institutions adapted by integrating various online platforms like Google Classroom, adopting a mixture of classroom, workshop, on-the-job training, and distance learning approaches. Similarly, Hashim and Hamidon (2022) emphasized the importance of blended learning methods which combine face-to-face and online instruction, thereby supporting 21st-century skills development and addressing disruptions in teaching processes.

A critical aspect of digital learning adoption is the acceptance and utilization of Learning Management Systems (LMS). Edeh et al. (2021) explored vocational educators' use of LMS in Nigerian TVET institutions, examining factors such as gender, experience, and perceptions. Their path analysis revealed that educators' experience fully mediated the relationship between their LMS skills and actual LMS usage, highlighting the need for focused capacity building among vocational educators to raise technology adoption levels. Ahmad et al. (2023) reinforced this by identifying key acceptance factors for LMS in TVET institutions, including system quality, service quality, information quality, motivation, self-discipline, and practical training. Their study suggested that addressing these factors could significantly improve LMS usage and the quality of teaching and learning activities in TVET.

B. Emerging Technologies and Their Role

Emerging technologies such as augmented reality (AR), digital mind maps, and multimedia tools play transformative roles in enhancing practical skills training within TVET. Abdul Hamid et al. (2024) investigated TVET instructors' perceptions of AR for skill training and found overall positive attitudes. The deployment of AR was seen to augment the learning process by offering immersive and interactive experiences, though challenges like students' acceptance and technology barriers were acknowledged. This aligns with Razak et al.

(2022), who evaluated digital mind maps usage among Malaysian TVET students and reported favorable perceptions with the potential to stimulate creativity and design thinking, thus enriching technical skills acquisition.

Moreover, Razali et al. (2023) studied multimedia elements in digital teaching and learning focused on art content within TVET. They validated multimedia components that impact emotional, subjective, execution, and psychological domains, indicating multimedia's significant influence on enhancing digital pedagogy quality in TVET art education.

With the acceleration of the Industrial Revolution 4.0 (IR4.0), integrating related competencies into TVET curricula is vital for workforce readiness. Ngatiman, Sulaiman, and Wong (2023) identified curriculum review, workforce provision, infrastructure, industry relations, and educational engagement as key challenges in implementing IR4.0 elements. Their findings underscore the urgency to incorporate IR4.0 skills, including digital literacy, automation, and data analytics, into TVET to meet evolving industrial standards. Likewise, Lai Chee Sern et al. (2021) highlighted the importance of embedding green skills and problem-solving abilities pertinent to environmental sustainability, further asserting the necessity to update curricula to reflect these broader sustainability and technological imperatives.

C. Teacher Training and Competency Development

Teacher preparedness is central to harnessing digital innovations in TVET effectively. Diao and Qu (2024) developed a teaching competence framework tailored for TVET teachers addressing digital-age challenges. Their training program fostered significant competence improvements, confirming the efficacy of structured professional development in equipping teachers with technological, pedagogical, and content knowledge necessary for contemporary TVET delivery.

Complementing that, Mohammad Hafiz Salleh et al. (2022) examined factors influencing TVET teachers' Technological Pedagogical Content Knowledge (TPACK) competencies in Malaysia. Their findings revealed technological knowledge as the most dominant component, though overall TPACK was the least mastered. The mentoring role and school environment significantly influenced teachers' TPACK competency, underscoring the importance of supportive institutional environments and mentorship in fostering digital teaching competencies.

Mohamad Yunus and Hapni (2022) also emphasized the relevance of technology integration analysis among TVET lecturers, advocating for targeted professional development programs to enhance the interaction of technological, pedagogical, and content knowledge. This would improve teaching quality and student skill acquisition in alignment with IR4.0 demands.

Finally, the recruitment and motivation of quality TVET educators are recognized as crucial. Eze et al. (2022) conducted studies on pre-service TVET teachers in Nigeria, underscoring motivators such as positive role models, the intrinsic passion for teaching, and the willingness to support disadvantaged students. Their findings advocate for improved hiring measures and recruitment standards to attract and retain competent TVET educators who can navigate the challenges of digital and technological transformation in vocational education..

STRATEGIES FOR ENHANCING QUALITY AND EMPLOYABILITY IN TVET

A. Curriculum Reform and Skills Alignment

Curriculum reform is pivotal in bridging the widening gap between the skills provided by TVET programs and industry demands. Integrating employability skills, including communication, leadership, teamwork, and technological literacy, into TVET curricula is crucial for enhancing graduates' readiness for the workforce. Lai Chee Sern et al. (2021) identify that embedding green skills into polytechnic curricula in Malaysia addresses emerging environmental and sustainability needs, promoting eco-conscious competencies alongside traditional technical skills. Najib et al. (2022) underscore the importance of aligning curricula with national strategic goals to enhance graduate relevance and efficacy, suggesting frameworks such as the TVET Capability Approach

Framework for systematic curriculum enhancement. Additionally, the development of talent management modules aimed at empowering TVET graduates to become job creators has been validated as an effective tool to foster entrepreneurial spirit and critical soft skills like problem-solving and continuous learning (Abdul Wafi et al., 2023). Leadership development in TVET institutions is equally critical; Abdullah et al. (2021) propose structured leadership models comprising essential elements that prepare TVET leaders to drive institutional improvement and respond adaptively to evolving industry and educational dynamics.

B. Strengthening Industry-Tvet Collaboration

Sustainable enhancement of TVET quality demands robust partnerships between educational institutions and industry. Subri et al. (2022) developed a governance structure model reinforcing collaboration between Malaysian TVET-Engineering institutions and the automotive industry, demonstrating how governance frameworks can harmonize institutional objectives with labor market needs. Omovigho (2021) highlights the instrumental role of TVET in improving employability and socioeconomic outcomes within tech-based industries by nurturing relevant skills through effective industry engagement. Work-Integrated Learning (WIL) has emerged as a particularly effective strategy to address skill gaps and enhance experiential learning. Mesuwini and Mokoena (2023) report that WIL equips TVET lecturers with up-to-date industry skills, practical experiences, and professional networks, though challenges remain around supervision and access to advanced machinery. The nature of TVET lecturer learning through WIL, as explored by Mesuwini et al. (2021), further validates the importance of practical engagement by facilitating teamwork, troubleshooting, and industry collaboration, ultimately improving teaching quality and graduate performance.

C. Enhancing Digital Pedagogy and Technological Support

The rapid advancement of digital technologies and Industry 4.0 elements necessitates focused development of digital pedagogy within TVET. Policy initiatives aimed at digital pedagogy, such as those explored by Marzuki et al. (2023), emphasize objectives to boost instructors' competencies and incorporate digital tools effectively to produce digitally proficient graduates. Razak et al. (2022) identify key factors influencing the acceptance and utilization of Learning Management Systems (LMS) in TVET institutions, outlining the need for system quality, motivation, and practical training components tailored to TVET contexts. Professional development programs targeting integrated technology and pedagogy skills are pivotal; Mohammad Hafiz Salleh et al. (2022) found that mentoring roles and supportive school environments significantly influence TVET teachers' technological pedagogical content knowledge (TPACK) competencies. Moreover, art teachers demonstrate the significance of mastery in technological tools for effective TVET technology integration (Gbadegbe et al., 2023). Collectively, these findings indicate that concerted efforts in policy, infrastructure, and professional training are necessary to develop holistic technology integration strategies to enhance TVET teaching and learning experiences.

D. Addressing Perception and Enrolment Challenges

Negative perceptions of TVET pose significant barriers to enrollment and the sector's growth. Shaari et al. (2024) demonstrate that behavioral insights interventions focusing on environmental, social, and personal influences can effectively shift student attitudes toward TVET, reducing stigma and enhancing the appeal of skills education among high school students. In the Maldives, Sunny and Ismail (2023) find that poor public awareness, lack of career readiness, and negative societal views are key factors diminishing youth engagement with TVET, recommending national campaigns and strategic promotions via electronic media. Azeem et al. (2022) highlight the need to account for demographic differences in students' interest toward TVET programs, where gender and urban-rural divides affect engagement levels. To facilitate better enrollment outcomes, predictive models such as those developed by Hong et al. (2023) utilize classifiers to forecast student inclination toward TVET, enabling targeted strategies to support diverse demographic engagement. Omar and Desa (2023) reveal that although TVET is generally regarded negatively as a second-choice educational route, there is no significant gender or stream-based difference in perception, suggesting that awareness programs may be universally beneficial. Addressing these perception and enrollment challenges through data-driven and behaviorally informed interventions is essential for expanding and diversifying TVET participation.

TVET AND SUSTAINABLE DEVELOPMENT

A. Contribution of TVET to Economic Growth and Social Empowerment

Technical and Vocational Education and Training (TVET) plays a pivotal role in enhancing economic growth and fostering social empowerment by equipping individuals with relevant skills that improve their employability and earning potential. Empirical studies underscore the positive impact of TVET on graduates' employment status and income levels. For instance, Adhikari et al. (2023) conducted a comprehensive study in Nepal which demonstrated a substantial increase in employment among TVET graduates—from 8.8% before training to 58.2% after graduation—with significant improvements in average income. The study highlighted that engineering and health sector graduates achieved the highest income gains, and that male graduates earned considerably more than their female counterparts, pointing to gender disparities in economic outcomes post-TVET.

Similarly, research in South Africa by Tun and Juchelková (2022) emphasizes TVET as an empowering mechanism for learners, particularly those from low socioeconomic backgrounds, enabling them to break the poverty cycle and achieve greater self-reliance. Their qualitative findings reveal how TVET skills foster financial independence and enhance the quality of life for marginalized youth, showcasing TVET's transformative social effect.

In the context of Sarawak, Malaysia, Omovigho et al. (2022) affirm TVET's significant contribution to employment facilitation within technology-driven industries. Their qualitative research shows that remunerated TVET-related employment not only supports individuals' socioeconomic development but also contributes to broader community advancement. These findings align with the broader economic rationale positioning TVET graduates as key contributors to local and national economic development through skilled labor supply.

B. Integration of Sustainable and Green Skills

Beyond direct economic contributions, TVET is increasingly recognized as an essential vehicle for supporting sustainable development through the integration of green skills and environmental awareness. Integrating these competencies into TVET curricula aligns with global efforts to address climate change and promote sustainable industries.

Lai Chee Sern et al. (2021) examined the perspectives of engineering lecturers in Malaysian polytechnics and identified a comprehensive set of green skills needing incorporation into the curriculum, including environmental pollution management, natural resource stewardship, energy efficiency, recycling and reuse, and green technology exploitation. Their descriptive study indicates that while there is an awareness of the necessity to embed green competencies, actual curricular integration is still lacking, underscoring the gap between industry expectations and educational practice.

Hanafi et al. (2023) further contextualize this by suggesting that TVET's focus on sustainability-related skills and lifelong learning not only strengthens efforts toward Sustainable Development Goals (SDGs) but also enhances the adaptability and resilience of the workforce amid ongoing economic and environmental challenges. Their analysis supports the conclusion that sustainable development principles must be mainstreamed within TVET frameworks to ensure alignment with both international agendas and local industry demands.

Other studies reinforce the urgency of equipping TVET graduates with skills pertinent to the green economy and Industry 4.0, highlighting that integrating digital skills alongside environmental competencies creates a workforce capable of driving sustainable economic transformation (Ngatiman et al., 2023).

C. Future Directions and Policy Implications

Looking forward, the alignment of TVET policies with SDG targets and evolving labor market demands remains a critical area for development. Hanafi et al. (2023) advocate for a coherent approach whereby international, bilateral, and multilateral organizations reinforce TVET and lifelong learning as cornerstones in

achieving SDGs, particularly those linked to decent work and economic growth (SDG 8). They emphasize the need for policies that not only promote skills acquisition but also consider emerging labor market trends driven by technological advances and sustainable development requirements.

In Malaysia, Marzuki et al. (2023) propose the development of digital pedagogy policies tailored for TVET students, affirming that effective policy frameworks are required to enhance teachers' digital competencies and to foster a skills-oriented workforce that meets the demands of both Industry 4.0 and sustainable development.

Moreover, Omovigho et al. (2022) and Subri et al. (2022) highlight governance and institutional models enhancing collaboration between TVET institutions and industry as strategic mechanisms to create relevant, demand-driven skills curricula that resonate with national economic priorities and SDG commitments.

Similarly, Melesse et al. (2023) exemplify successful private-public development partnerships in Ethiopia that bridge the gap between curriculum design and industry needs, ensuring that TVET programs are contextually relevant and forward-looking in sustainable workforce development.

As the global economy pivots toward sustainability and digitalization, TVET policies must adapt accordingly by fostering synergy between education providers, industries, and policymakers. This includes advancing digital skills, investing in teacher capacity building, and implementing monitoring systems for quality assurance that reflect sustainability considerations, as highlighted by Marzuki et al. (2023) and further supported by Hanafi et al. (2023). These strategic directions will enable TVET to fulfill its potential as a driver of inclusive economic growth and a catalyst for achieving the Sustainable Development Goals.

D. Methodological Limitations in the Reviewed Literature

While the reviewed literature provides valuable insights, several methodological limitations must be acknowledged. Many studies employ small, context-specific samples, such as single-institution or single-region analyses. For instance, Auta and Onwusuru (2022), Edeh et al. (2021), and Omar and Desa (2023) each conducted studies within narrowly defined contexts, which limits the generalizability of their findings across national or global TVET systems.

Numerous studies also rely on cross-sectional surveys, restricting the ability to establish causal relationships—for example, between pedagogical innovations and actual employability outcomes. Wan Abdullah et al. (2022) and Ahmad et al. (2023) illustrate this limitation in their respective analyses. Research on technology integration similarly depends heavily on self-reported competencies; Mohammad Hafiz Salleh et al. (2022) and Mohamad Yunus and Hapni (2022) note that such measures often inflate lecturers' confidence and may obscure actual skill deficiencies.

Comparative inconsistencies further arise because the reviewed studies employ diverse methodological designs. Mesuwini and Mokoena (2023) adopt a qualitative case study approach, Marzuki et al. (2023) utilize the Delphi method, and Lai Chee Sern et al. (2021) employ descriptive survey designs. Such methodological variation complicates synthesis and weakens the overall evidence base.

Additionally, only a few studies adopt longitudinal or mixed-method approaches that are necessary to evaluate long-term impacts of TVET training, digital pedagogy, or industry–TVET partnerships. For example, Adhikari et al. (2023) and Melesse et al. (2023) demonstrate the value of such extended analytical approaches, though such studies remain limited in number.

Recognizing these limitations highlights a need for more robust, comparative, and longitudinal research designs to strengthen empirical understanding of TVET transformation, digital integration, and employability outcomes.

CONCLUSIONS

This review highlights the pivotal role of TVET in addressing workforce skill demands and fostering sustainable development, while also exposing persistent challenges such as significant skill mismatches,

pedagogical shortcomings, and institutional fragmentation. The growing adoption of digital innovations and integrated pedagogical models offers promising solutions to enhance TVET quality and relevance. Strategic curriculum reforms incorporating employability, green, and digital skills, coupled with strengthened industry partnerships, are essential for bridging gaps between education and labor market needs. Furthermore, addressing perception issues and improving enrollment diversity remain critical for TVET's broader impact. Aligning TVET initiatives with Sustainable Development Goals presents a compelling pathway for inclusive economic growth and social empowerment. Future research and policy efforts should prioritize scalable digital integration, leadership in governance, and expanded awareness to maximize TVET's role in preparing a competent, adaptable workforce for the evolving global economy.

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