

Embedding Web-Based Learning into Industry 4.0-Oriented TVET: Strengthening Future Workforce Competencies

Muhammad Ikhwan Hafiz Bahrum^{1*}, Saifullizam Puteh¹, Muhammad Haziq Mazlan¹,
Nor Lisa Sulaiman¹, Kahirol Mohd Salleh¹, Rosnawati Buhari²

¹ Faculty of Technical and Vocational Education, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia

² Faculty of Civil and Environmental, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia

*Corresponding Author: gb240167@student.uthm.edu.my

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Abstract: *The Fourth Industrial Revolution (IR4.0) is reshaping global education and employment dynamics, especially influencing Technical and Vocational Education and Training (TVET). This study examines Malaysia's strategic approach to IR4.0 by analysing national policies, digital integration, and institutional reforms. It underscores the cultivation of IR4.0 talent through hybrid skill frameworks that integrate technological proficiencies, including digital literacy, IoT, AI, cybersecurity, and automation, with essential non-technical abilities such as creativity, adaptability, and problem-solving. The core of this transition is the incorporation of digital technologies, such as web-based interactive e-modules created with Weebly, which improve self-directed learning and industry-relevant skills. This study, grounded in the National TVET Policy 2030 and the UNESCO TVET Strategy 2022-2029, emphasises how policy-driven digital pedagogy at vocational colleges promotes inclusive, future-ready education in accordance with the Sustainable Development Goals (SDGs). The paper outlines the possibilities and constraints of technologies such as IoT and online systems in providing flexible, scalable, and engaging learning experiences. This essay enhances the ongoing discussion on digital transformation in TVET by providing a comprehensive view of the interplay between educational technologies, curriculum design, and talent development to foster a competitive and skilled national workforce in the IR4.0 era.*

Keywords: IR4.0; TVET; e-Modules; Web-Based Learning; Weebly

1. Introduction

Multiple phases of technological transformation have influenced the Industrial Revolution. In the First Industrial Revolution, human labour was supplanted by steam and water power in manufacturing processes. The Second Industrial Revolution, marked by the advent of electricity and significantly accelerated mass production, followed subsequently. The Third Industrial Revolution, marked by the emergence of computers and information technology, promoted automation throughout various industrial sectors. The implementation of the Fourth Industrial Revolution (IR4.0) poses several significant challenges, including elevated investment costs, technological immaturity, a shortage of skilled labour, cybersecurity threats, unemployment, and privacy violations, as noted by Kumar, Suhaib, and Asjad (2020). IR4.0 offers numerous advantages, including enhanced system interaction, process optimisation, production flexibility, data transparency, system integrity, and increased levels of automation

and digitisation. The implementation of advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), robotics, autonomous vehicles, cloud computing, 3D printing, and emerging digital innovations like virtual and augmented reality can facilitate these benefits. The successful implementation of IR4.0 requires a comprehensive plan that mitigates risks while strategically leveraging technology to maximise its benefits, with due consideration for security, ethical issues, and human capital development. The implementation of advanced automation technology has profoundly transformed industrial processes and diminished the need for manual labour (Majid et al., 2022). IR4.0, propelled by advanced technologies such as the IoT, AI autonomous systems, 3D printing, smart networks, and big data analytics, transcends previous industrial revolutions by integrating physical, digital, and biological systems (Rymarczyk, 2020). These technologies enable intelligent products and more efficient manufacturing processes. The digital transformation enabled by IR4.0 has altered data interchange and system automation, encompassing cyber-physical system integration and intelligent computing (Ellitan, 2020).

2. Key Competencies in IR4.0 Talent

The term "IR 4.0" refers to the rapid advancement of digital technologies that blur the boundaries between the digital, biological, and physical realms (Trauth-Goik, 2021). The utilisation of Big Data, IoT, AI, Cloud Computing, and devices to digitally transform integrated production, processing, and online information flow. Caruso (2018). The industrial and service sectors are rapidly requiring graduates with specific and relevant skills, notwithstanding the rapid evolution of IR4.0 technologies and a significant talent deficit capable of meeting these advancements (Abdullah, Humaidi & Shahrom, 2020). Consequently, within the context of IR4.0, the Hybrid Skills Framework was introduced. This framework denotes a systematic approach for integrating and enhancing both technical and non-technical skills. Digital literacy, programming, cybersecurity, big data, IoT, automation, virtual reality/augmented reality (VR/AR), and systematic data analysis and interpretation are all critical technological competencies for Industry 4.0. A range of non-technical competencies and skills, such as knowledge, creativity, problem-solving, and critical thinking, is essential for digital technology. IR4.0 underscores the importance of merging technological and non-technical skills. Industry 4.0 requires significant adaptation and the acquisition of knowledge and skills to manage technology (Kipper et al., 2021).

Strategies aim to ensure the effective development of IR4.0 skills within the hybrid framework of IR4.0. Educational reform via collaboration among the government, educational institutions, and industry; implementing training programs or seminars pertinent to IR4.0; and enhancing the curriculum to integrate both technical and non-technical abilities from early education. Effectively cultivating IR4.0 talent will likely necessitate collective support. Malaysia has initiated the integration of Industry 4.0 frameworks through initiatives such as the National Policy on Industry 4.0; nevertheless, significant barriers to its implementation persist. According to Chornenka (2025), countries such as Germany possess established ecosystems that integrate apprenticeships, vocational education, and substantial industry participation in curriculum development via their Industry 4.0 initiative. Conversely, South Korea emphasises national R&D investment and AI-driven reskilling programs to ensure that people continually adapt to digital transformations. Australia has a stacking, modular certificate system that allows students to enhance their competencies through concise, industry-relevant degrees (Pramesti, Savandha & Amelia, 2025).

According to Yunus et al. 2024, Malaysia's current projects, while promising, suffer from inconsistent curriculum changes, fragmented implementation, and a misalignment between industry aspirations and academic outcomes. For example, non-technical skills such as critical thinking and interdisciplinary collaboration are rarely assessed or systematically developed, despite the availability of IR4.0 technical subjects at polytechnics and select universities. To establish a future-ready workforce, Figure 1 illustrates the strategic interconnection among IR4.0 technology, the cultivation of hybrid skills, and the synchronisation of national and international Technical and Vocational Education and Training (TVET) programs (UNESCO). The framework's three principal pillars are the standardisation of TVET legislation, the use of IR 4.0 technologies, and a hybrid skills framework encompassing both technical and soft skills. These characteristics influence two main implementation domains: operationalisation within vocational institutions and the integration of digital technology in TVET. These domains jointly facilitate the advancement of web-based education and online modules via platforms like Weebly, which function as the delivery system for providing students with adaptable and technology-enhanced learning experiences. The objective of the framework is to cultivate a workforce that is future-ready and capable of meeting the requirements of the IR4.0-driven labour market. This framework underscores the necessity of integrating advanced technology, regulatory structures, and digital pedagogical design to modernise the TVET system and improve human capital development in accordance with current and future industry requirements.

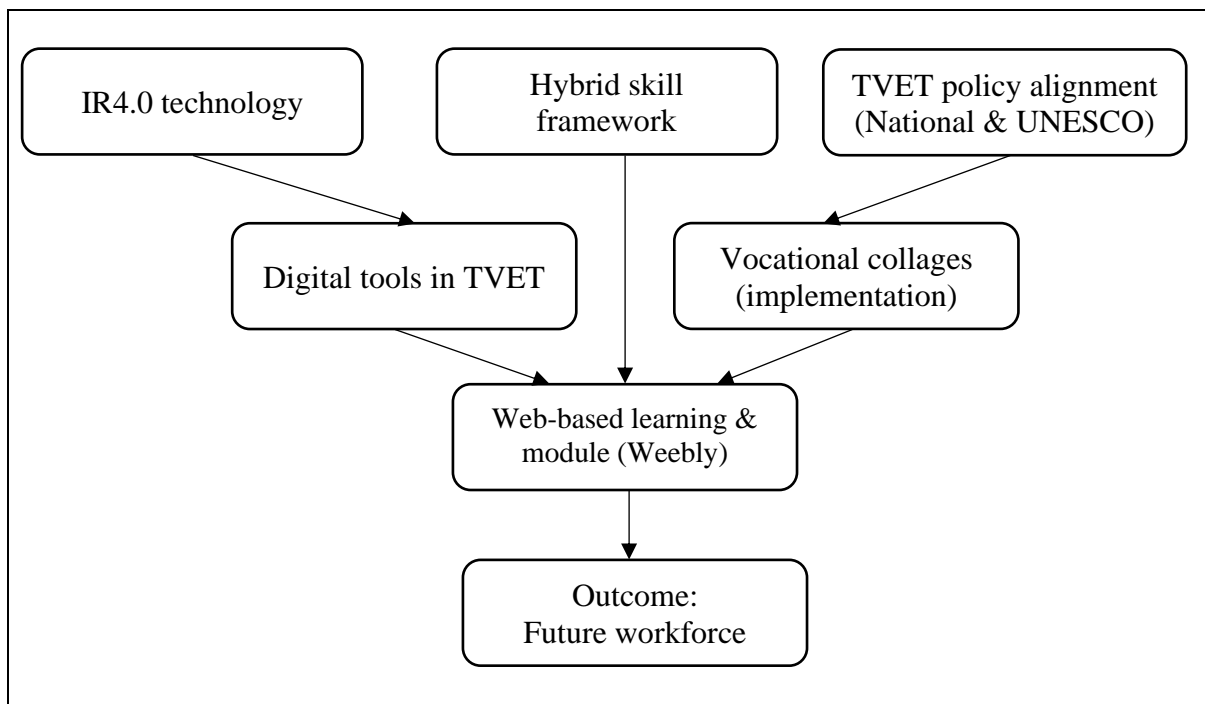


Figure 1: Conceptual Framework

3. Strategy for TVET 2022-2029

Three main priorities are highlighted in the UNESCO Strategy for TVET 2022-2029: (i) fostering inclusive and resilient societies; (ii) supporting economic transitions toward sustainable development; and (iii) developing skills for learning, work, and life (Sunny et al., 2023). Through adaptable digital learning platforms, micro credentials, and skills specific to the digital and green economy, the approach fosters digital transformation (Wu & Yang, 2024).

To improve employment-relevant skills, promote the digital and green economies, and foster inclusive communities, this plan aims to modernize TVET systems worldwide in seven years (Amin et al., 2023; UNESCO, 2019). Through the provision of pertinent and forward-looking skills to the workforce, the policy guarantees that TVET programs are able to adapt to the technological needs of IR 4.0. Reorienting TVET education and training toward future employment while utilizing technology improvements is one of the practical steps under this plan. The Sustainable Development Goals (SDGs) are supported by each of the three strategic priorities: SDG 4 (quality education and lifelong learning) is supported by the first; SDG 8 (decent work and economic growth) and SDG 11 (inclusive cities) are supported by the second; and SDG 16 (peaceful and inclusive societies) is supported by the third.

4. Malaysia Policy Alignment with IR4.0 and TVET Transformation

The National TVET Policy 2030, which was created to expedite the establishment of TVET programs throughout Malaysia, is a complement to the 4IR Policy. Its goal is to use a workforce that is knowledgeable and capable of propelling the nation toward developed status. Making TVET adaptable, inclusive, and responsive is a key component of the mission (Sekretariat Majlis TVET Negara, 2024). The policy's main tenets include creating graduates who are prepared for the workforce, promoting TVET as a desirable career option, improving institutional relevance, and raising the standard of education. Six major areas are covered by the National TVET Policy: work-based learning, exposure to the industry, industry-recognized standards, and substantial practical components (50-70%). These pillars demonstrate a dedication to a thorough and coordinated governance structure, top-notch educational standards, productive industrial cooperation, long-term funding, and a cohesive TVET branding initiative. Such programs enhance Malaysia's ability to handle upcoming technical and economic problems while also advancing the goals of the 4IR Policy.

The Ministry of Education Malaysia launched the Digital Education Policy (DEP), a strategic program designed to transform the country's educational system and bring it into line with the ever-increasing demands of the digital age. Besides fostering digital literacy, this strategy also aims to nurture students who are innovative, critical thinkers, globally competitive, and capable of using technology in a responsible manner (Ministry of Education Malaysia, 2023). To strengthen knowledge acquisition, digital skills, and digital values among the education community, digital education is a teaching and learning (T&L) approach that creatively, innovatively, and holistically integrates information and communication technology (Sidek, 2023). The development of digitally fluent pupils, improving teacher capabilities, visionary educational leadership, sustainable infrastructure and infostructure development, and the production of high-quality digital content are the six main pillars around which the DEP is built.

5. Technical and Vocational Education and Training (TVET)

To effectively embed web-based learning within Industry 4.0-oriented education, it is essential to understand the foundation and evolution of TVET in Malaysia. As a strategic educational pathway, TVET plays a pivotal role in preparing a future-ready workforce equipped with both technical and non-technical competencies aligned with IR4.0 demands. Since the 1950s, when technical and vocational schools were first established, Malaysia's TVET has been continuously developed (Majumdar, Araiztegui & Tknika, 2020). Engineering, mechanics, electronics, and agriculture were among the core disciplines (Hassan, Shamsudin & Mustapha, 2019). By implementing a competency-based education and training system, the country is

demonstrating its commitment to enhancing TVET's role in workforce preparation (ASEAN Secretariat, 2020). Both domestically and internationally, TVET is essential in addressing the skills gap between industry demands and educational output. In order to meet present and future labor market demands, the Malaysian government has made TVET a priority by growing its institutions and programs (Amin et al., 2023). The first stage of organized TVET growth was the founding of the Industrial Training Institutes (ILP) and National Youth Skills Institutes (IKBN). With 1,345 TVET institutions created nationally by December 2023, Malaysia demonstrated the sector's growing potential in bolstering the country's economic progress (Anafi & Noor, 2024).

Based on TVET Malaysia (2024), The evolution of TVET institutions in Malaysia began during the pre-independence era with the establishment of the Teacher Technical School in 1906. This development was further strengthened in the post-independence period through the establishment of Industrial Training Institutes and Vocational Secondary Schools to meet the demands of the labor market. The Vocational Education change Strategic Plan (PSTPV) and the Malaysia Education Blueprint 2013-2025 were the driving forces behind TVET's change as we entered the twenty-first century. With the addition of three new institutions lately, Malaysia offered more than 250,000 spots in June 2024 over 1,395 TVET institutes spread across 12 ministries (MySPIKE JPK & MQA, 2024).

6. Vocational Collages as Strategic TVET Institutions

Building upon the strategic importance of TVET, vocational colleges under the Ministry of Education Malaysia serve as key institutions in operationalising IR4.0 initiatives. A vital component of the national TVET ecosystem, vocational colleges run by the Malaysian Ministry of Education provide students who are interested in skills-based and hands-on learning with organized educational routes. The Malaysian Vocational Certificate (SVM) and the Malaysian Vocational Diploma (DVM), which are offered by these schools over a four-year period, are the two main credentials they provide. With an emphasis on practical training and real-world applications, the program aims to provide students with pertinent vocational skills that are suited to industry demands (Adnan et al., 2021). The eight-semester curriculum focuses on core skills in the early stages and industry training and specialization in the later stages. The ratio of academic to vocational topics is shown in Table 1, which indicates a significant bias in favor of hands-on training to guarantee employment.

Table 1: Vocational College Program Course Composition (Rus, 2023; KPM, 2022)

Content	Program	
	SVM	DVM
Vocational	70%	80%
Academic	30%	20%
Total	100%	100%

Vocational Colleges offer a broad array of disciplines, including hospitality, agriculture, creative design, business, manufacturing, information, and communication technology (ICT), mechanical, electrical, and civil engineering. This diversity allows students to pursue careers aligned with their interests and the evolving labour market. (Demin & Mohamad, 2023; Affan, 2022). However, not every Vocational College offers electrical technology programs. The availability of these programs depends on several factors, including institutional capacity, regional economic demands, and strategic educational planning by the Ministry of Education. Table 2 details the list of Vocational Colleges throughout Malaysia.

Table 2: List of Vocational Colleges Throughout Malaysia (BPLTV,2023)

State	Number of Vocational Collage	Number of Student
Johor	11	7460
Kedah	5	4446
Kelantan	6	4526
Melaka	3	2368
Negeri Sembilan	6	4738
Pahang	8	4827
Perak	10	7188
Perlis	2	1941
Pulau Pinang	5	3341
Sabah	8	5628
Sarawak	6	3693
Selangor	8	6344
Terengganu	5	3377
Wilayah Persekutuan Kuala Lumpur	2	1643
Wilayah Persekutuan Labuan	1	583

Through the integration of real-world experiences, industry exposure, and project-based learning, these institutions play a crucial role in creating a workforce that is prepared for the future. They are strategically positioned to help turn Malaysia into a competitive, skilled country because of their synergy with government initiatives like the 4IR strategy and the government TVET Policy 2030.

7. Web Based Education

Web-based technologies have fundamentally altered the manner in which individuals access, process, and distribute information in the digital era. In general, the term "web" is used to describe the World Wide Web, an internet-based infrastructure that facilitates the retrieval and interaction of documents and resources through browsers. In the absence of installation, web applications can be accessed from any internet-enabled device and operate on servers located at a distance (Polik & Schmidt, 2021). Web platforms are developed by integrating server-side and client-side technologies. HTML, CSS, and JavaScript are responsible for managing the structure, appearance, and interaction of a webpage on the client side. Frameworks and languages such as PHP, Python, Java, and Node.js are responsible for data processing, authentication, and database connectivity on the server side (Sadriddinovich & Muhiddi-novna, 2024). HTTP requests and responses facilitate client-server communication and ensure that dynamic content is transmitted in response to user input.

Web-based programs have gained popularity in education due to their scalability, accessibility, and collaborative capabilities. They enable students to participate in discussions, complete assessments, and receive feedback asynchronously, as well as access course materials at their convenience. Platform independence, real-time data interaction, centralised updates, and multiuser access are among the primary attributes of web-based systems. Despite their advantages, web systems have several disadvantages, such as the potential for disruptions in the event of a server attack, the dependence on internet access, and data security threats. Nevertheless, web applications are advantageous instruments in both professional and educational environments when they are equipped with responsive interfaces, user authentication, and effective encryption (Schneider, 2024).

8. E-Module as Instructional Tool

Electronic learning modules, or e-modules, are organized digital learning resources intended to facilitate autonomous and self-directed learning. E-modules, in contrast to conventional printed modules, are interactive and available via digital platforms. To improve student engagement, they incorporate multimedia components including audio, video, animations, simulations, and quizzes (Azis & Yulkifli, 2021). They are usually created in accordance with certain course requirements or curricula, and their goal is to encourage self-directed learning while giving students freedom in the way and timing of their interactions with the material. E-modules serve as self-contained educational units that lead students through learning objectives, theoretical information, hands-on activities, and self-assessment resources, claims Sutirman (2019). They are especially helpful in modern educational environments where remote learning and digital literacy are being given more importance. Without continual instructor supervision, e-modules enable students to take charge of their own learning and expand their conceptual knowledge. Clear learning objectives, the integration of theoretical and practical material, digital instructional design, guided supervision, skill evaluations, and self-evaluation mechanisms are all essential components of an effective e-module design (Akhmedova & Turdaliyev, 2022). Using interactive and visual components encourages active participation and improves idea memory, particularly for abstract or difficult subjects. According to research by Elistiana, Novita & Ginting (2024), interactive e-modules have the potential to greatly enhance student performance and attain high levels of content validity.

8.1 Guidelines In E-Module Development

Planning, content creation, and assessment are the three main stages of an instructional design process that is used to create successful e-modules. Every stage guarantees that the final module is relevant to the needs of the learner, pedagogically sound, and technologically accessible (Pulukadang et al., 2020). Teachers choose relevant information, decide on a delivery method, and specify learning objectives during the preparation stage. This entails determining the requirements of the students, choosing appropriate multimedia resources, and matching teaching methods to the digital literacy levels of the students. Successful planning, according to Nasution & Siregar (2021), entails cross-platform accessible design, curriculum alignment, and learning context analysis. The creation of dynamic, multimedia-rich educational resources is the main goal of the content development phase. This entails including voiceovers, movies, infographics, animations, quizzes, and links to outside resources. To facilitate a seamless learning process, user interface design and navigation structure must be simple and distraction-free (Hadjeris & El Moussami, 2021). Lastly, the assessment process entails using learning analytics, pilot studies, and feedback gathering to test the efficacy of the e-module. According to Pedro & Derasin (2022), iterative design changes should be informed by real-time analytics and evaluations that focus on knowledge, abilities, and attitudes. This guarantees that the e-module will continue to be successful in accomplishing its educational objectives.

8.2 Advantages and Limitations of E-Modules

E-modules offer several benefits as teaching resources. Flexibility, accessibility, engagement, and adaptability to different learning styles are some of its main advantages. For students who need individualized teaching or who prefer self-paced learning, e-modules are particularly helpful (Thuneberg et al., 2018; King & Robinson, 2009). Their use of multimedia elements improves student comprehension and motivation. Through formative evaluations and integrated quizzes, e-modules can also offer instant feedback, enabling learners to monitor their progress and reinforce comprehension in real time (Rochsun & Agustin, 2020; Pulukadang et al., 2020).

E-modules do, however, have certain drawbacks. According to certain research, student engagement may be lowered by activities or examples in some e-modules that are not relevant to real-world applications. Furthermore, consistent internet connectivity and digital infrastructure are frequently required for access to e-modules, which can be problematic in environments with limited resources (Ndruru & Amdayani, 2023). Notwithstanding these difficulties, well-designed e-modules continue to have substantial instructional value. E-modules are effective tools for encouraging active and independent learning in contemporary educational settings when they are created in accordance with user-centered design principles and matched with curricular objectives.

9. Integration of Web-Based Interactive E-Modules as Teaching Aids

The distribution of educational information has changed because of the growing use of web-based technologies in the classroom, with interactive e-modules serving as essential teaching tools. These resources, which are housed on internet platforms, give students flexible, interactive access to learning materials at any time and from any location (Ehlers, 2009). Web-based e-modules combine text, video, graphics, and evaluations into a single platform, offering a seamless educational experience that is suited to the demands of the twenty-first century. This kind of integration improves student engagement and retention of the material in addition to facilitating autonomous learning. With features like multimedia presentations, real-time feedback, and integrated quizzes, web-based platforms make it easier for teachers and students to engage. Web-based learning tools that provide guided discovery and idea reinforcement can prolong cognitive growth, claim Bernadine et al. (2022).

The accessibility, reusability, visual clarity, and interactive qualities of web-based teaching aids make them beneficial (Norman & Nasir, 2025). Additionally, a lot of platforms provide interaction with Learning Management Systems (LMS), which promotes effective student progress monitoring and individualized feedback systems. A learner-centered, technologically integrated educational approach is supported by this pedagogical movement toward web-enhanced learning resources.

10. Pedagogical Features of Web-Based Instructional Media

Features that make web-based e-modules useful for teaching and learning are included into their design. These consist of asynchronous accessibility, adjustable pacing, user-friendly interfaces, and multimedia integration videos, animations, and infographics (Astalini et al., 2019). When integrated into virtual laboratories or online classrooms, their self-contained structure promotes independent learning while easing teamwork. Digital learning environments improve student performance by encouraging active engagement and lowering cognitive overload, according to Smart & Cappel (2006). Additional pedagogical advantages include connection with contemporary curricular requirements, instant formative feedback, and responsiveness to student variety. Web-based educational materials are especially well-suited for remote, hybrid, or flipped classroom formats because of these characteristics.

10.1 Integrating Weebly in the Development of Interactive Web-Based E-Modules

Weebly has emerged as a viable alternative for educators seeking to develop interactive web-based e-modules. As a website development platform, Weebly offers a user-friendly interface that enables the creation of instructional websites without requiring programming expertise (Kumar & Sharma, 2021). Its customizable templates and multimedia embedding capabilities allow educators to design themed learning portals that incorporate interactive tasks, embedded

videos, quizzes, and downloadable materials, all of which can be tailored to support diverse learning needs. Weebly for education provides additional features that enhance the teaching and learning process, including student account management, privacy configuration, and feedback mechanisms (Hauck et al., 2020; Liu et al., 2020). Its accessibility and flexibility make it suitable for both formal classroom settings and informal learning environments. Furthermore, the platform supports the development of visually engaging and personalised content, allowing students to explore topics independently while receiving structured guidance from instructors (Bećirović, 2023; Gavi & Mavengere, 2019).

Recent studies have highlighted the pedagogical potential of web-based platforms such as Weebly in promoting learner autonomy, differentiated instruction, and digital literacy (Yunus et al., 2023; Norazah et al., 2022). The integration of such platforms aligns with the principles of Education 4.0, which emphasise flexible, student-centred learning supported by technology (Hussin, 2018). Additionally, Weebly's compatibility with mobile devices and cloud-based access enhances its practicality in blended and remote learning contexts, particularly in regions with limited infrastructure (Zainuddin & Perera, 2021). These capabilities position Weebly as a practical and adaptable solution for institutions aiming to modernise instructional delivery and expand access to digital learning resources.

10.2 Advantages and Challenges of Using Weebly for E-Modules

There are a number of benefits to using Weebly while creating web-based e-modules. It is an affordable and scalable solution because to its user-friendly interface, free hosting possibilities, and multimedia compatibility (Belinda et al., 2024). It enables the smooth integration of downloaded content, asynchronous learner involvement, and audio-visual resources. Through comment sections and tools for submitting assignments, Weebly also facilitates communication between teachers and students. However, drawbacks include reliance on internet connectivity, restricted authority over sophisticated coding or customisation for sophisticated educational resources, and sporadic limits with free tier services. Even with these drawbacks, Weebly is still a very practical tool for teachers who want to make e-modules that are both aesthetically pleasing and pedagogically solid, particularly in environments that support blended learning and digital literacy.

11. Conclusion

The integration of IR4.0 technologies into the TVET ecosystem is a critical turning point in Malaysia's pursuit of a workforce that is both technologically adept and prepared for the future. This transition is driven by the urgent necessity to cultivate IR4.0 professionals who possess both technical and non-technical abilities, as well as innovations such as IoT, AI, and big data. The Hybrid Skills Framework provides a strategic foundation for addressing the current talent divide by highlighting the importance of digital literacy, programming, automation, and essential soft skills such as flexibility, creativity, and problem-solving. Simultaneously, national initiatives such as the National TVET Policy 2030, the UNESCO TVET Strategy 2022-2029, and the UNESCO TVET Strategy 2022-2029 prioritise a systemic reform approach that involves the creation of inclusive and sustainable learning environments, curriculum modernisation, and stakeholder engagement. Vocational colleges are significant change agents at the institutional level due to their provision of industry-standard, practice-oriented curricula. Their emphasis on practical experience and industry-driven teaching is further reinforced by the utilisation of interactive e-modules and web-based technology. Thanks to platforms such as Weebly, educators can now develop digital curricula that are multimedia-rich and immersive, which promotes self-directed learning and increases student engagement. Despite

obstacles such as infrastructural restrictions and disparities in digital proficiency, the utilisation of e-modules and IoT-driven solutions exhibits significant potential in fostering educational access, equity, and creativity. Malaysia's deliberate endeavours to harmonise institutional practice, digital innovation, and educational policy ultimately demonstrate a progressive and unified response to IR4.0 requirements. Maintaining cross-sectoral collaboration, investing in educator capacity-building, and iteratively improving digital technologies are all essential for assuring long-term effectiveness. By implementing these initiatives, TVET has the potential to transform into a forward-thinking, robust institution that can supply a highly skilled IR4.0 workforce that meets the needs of both domestic and international markets.

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Conflict of Interest Statement

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

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