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ORIGINAL ARTICLE

Advancing digital transformation in TVET through international cooperation: Approaches by the UNESCO Chair on Digitalization in TVET

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ABSTRACT

This article examines diverse approaches to international cooperation aimed at advancing digital transformation in technical and vocational education and training (TVET), using the UNESCO Chair on Digitalization in TVET at Shenzhen Polytechnic University as a case study. Through a thematic analysis of the Chair's activities from March 2023 to March 2024, the study has identified four key approaches: (1) fostering a global dialogue on the digital transformation of TVET; (2) contributing to a digital learning community *via* open educational resources; (3) strengthening regional TVET capacities for digital transformation through leadership and teacher training; and (4) building a synergistic TVET ecosystem through cross-sectoral partnerships. The findings highlight the Chair's role in facilitating knowledge sharing, capacity building, and collaborative projects among global TVET stakeholders. Challenges related to digital disparities and ensuring the long-term sustainability of cooperation are also discussed. This study contributes to the emerging knowledge base on international cooperation for TVET digital transformation and provides insights for future practice and research.

Key words: technical and vocational education and training, digital transformation, international cooperation, UNESCO

INTRODUCTION

The exponential growth and integration of digital technologies across all sectors have given rise to the digital economy, which underscores the imperative for the digital transformation of technical and vocational education and training (TVET). This transformation is crucial for ensuring that TVET systems can effectively equip learners with the skills they need to thrive in the digital age. However, the pursuit of digital transformation in many countries is significantly challenged by the digital divide, which involves a complex set of disparities in access to technology, digital skills, and opportunities that can hinder equitable participation in digitally enhanced learning and training.[1]

In this context, international cooperation, often facilitated by organizations such as the United Nations Educational, Scientific and Cultural Organization (UNESCO), has emerged as a key strategy for addressing the digital divide and advancing global digital transformation in TVET by promoting the sharing of knowledge, resources, and best practices across borders.

While international cooperation in TVET is well-established, it primarily focuses on general topics, with initiatives specifically targeting digital transformation only recently beginning to emerge.[2,3] Such initiatives are primarily being led by major international organizations, with individual TVET institutions often playing a more limited role in their design and implementation.

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However, as the digital transformation of TVET becomes increasingly crucial, it is important for TVET institutions, especially those in developing countries, to take a more proactive approach and engage in closer collaboration with international partners. Such collaboration can enable these institutions to build capacity, jointly develop strategies to address the challenges posed by the digital divide, and accelerate the digital transformation of TVET worldwide.

Despite the growing recognition of the importance of international collaboration in driving digital change in TVET, there is a limited understanding of the effective design, implementation, and sustainability of such projects. Current initiatives in this area are still in their early stages, so concrete examples of international projects aimed at enhancing the digital transformation of TVET need to be examined. To address this gap, this study focuses on the UNESCO Chair on Digitalization in TVET, which is hosted by Shenzhen Polytechnic University (SZPU) in China, as a representative case of digital-focused international cooperation. Through a comprehensive analysis of the Chair's key projects, activities, and outcomes during a one-year period (*i.e.*, March 2023-March 2024), the study seeks to contribute to the emerging knowledge on international cooperation for TVET digital transformation and to provide practical insights that can inform the strategies of other TVET institutions with similar interests.

This article is structured as follows: Section Two reviews the literature on the imperative and challenges inherent to the digital transformation of TVET and examines the current landscape of international cooperation in this field. Section Three outlines the case study method employed in this study. Section Four presents the findings and identifies four key approaches exercised by the UNESCO Chair on Digitalization in TVET in its global engagement to advance TVET's digital transformation. Section Five provides a synthesized discussion on the content, participants, aim, means, and support system of cooperation, before the paper concludes with suggestions on future practices and research directions.

LITERATURE REVIEW

The imperative of digital transformation in TVET

The exponential growth and integration of digital technologies across all sectors underscore the call for the digital transformation of TVET. The rapid advancement of technologies, such as artificial intelligence (AI), robotics, and the Internet of Things, has given rise to the digital economy, a phenomenon characterized by the increasing prevalence of economic activities and transactions that are based on digital technologies.[4] Two concurrent trends drive this digital transformation: the industrialization of digital technologies, which has accelerated the growth of the high-tech industry, and the digitalization of traditional industries, such as agriculture, manufacturing, and transportation, which are increasingly adopting digital solutions to enhance efficiency and productivity.[5] The COVID-19 pandemic expedited the digital transformation, compelling numerous businesses to transition to online platforms and digital solutions to sustain their operations and engage with their clientele.[6] This rapid expansion of the digital economy highlights its growing importance and the need for all businesses and organizations to adapt accordingly.

The technological evolution is reshaping job roles, creating new professions, and phasing out others. The World Economic Forum has estimated a global structural labor market churn (*i.e.*, the simultaneous creation and destruction of jobs) of 23% from 2023 to 2027, with 69 million new jobs emerging from the collaborative work between humans and machines and a decline of 83 million jobs due to the increasing automation of routine tasks.[7] This labor market change will result in a demand for new skills and a concomitant devaluation of others. A study in Europe projected that companies with a high degree of digital technology adoption would see their demand for well-skilled workers, technicians, and master craftsmen increase by 20%-30% alongside a substantial reduction in the need for a semi-skilled and unskilled workforce.[8] TVET, with its emphasis on practical, work-oriented training, is uniquely positioned to address this increased demand. However, the traditional outputs of TVET programs are often not well aligned with the digital skill sets sought by the industry, which indicates a critical disconnect.[9] This discrepancy emphasizes the urgent need for the comprehensive digital transformation of TVET to ensure that it remains relevant and can effectively serve the needs of the modern workforce.

The importance of digital transformation also lies in its potential to improve the quality and standing of TVET. The education sector recognizes the integration of digital technologies as a means to enhance learning outcomes, expand access, and foster innovation in teaching and administrative practices.[10] In TVET, digital transformation can enable more flexible, learner-centered pedagogies, facilitate the development of 21st century skills, and strengthen engagement with industry partners.[11] However, compared to the progress made in digital transformation in K-12 and higher education, the pace of change in TVET has been slower, as information and communication technology (ICT)-based innovations, research, and applications have been found to be less effectively integrated across TVET training

cycle components and functional areas.[12] This lag threatens to widen the gap between the skills of TVET graduates and the needs of the digital economy. Notwithstanding, by fully engaging in digital transformation, TVET can reposition itself as a key driver of inclusive digital upskilling and equip learners from diverse backgrounds with the necessary competencies to thrive in the digital age.

Digital divide as a major challenge to global TVET digital transformation

In the global pursuit of TVET digital transformation, the digital divide has emerged as an immediate and significant barrier. The Organisation for Economic Cooperation and Development (OECD) defines the term "digital divide" as "the gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard to both their opportunities to access ICTs and to their use of the Internet for a wide variety of activities".[13] The term encompasses disparities in physical access to technology (the "access divide"), the skills needed to properly engage in the digital world (the "skills divide"), and the benefits derived from utilizing digital technology (the "benefits divide").[14,15] These dimensions present significant challenges to the digital transformation of TVET worldwide.

As regards the access divide, the International Telecommunication Union reported that an estimated 2.6 billion people, or one-third of the global population, remained offline in 2023. While 93% of the population in high-income countries has access to the Internet, this figure is dramatically reduced in low-income countries, where only 27% of the population has access to this service.[16] Such disparities are just as stark for mobile broadband subscriptions. The rate of 148 subscriptions per 100 inhabitants in high-income countries is nearly four times higher than that in low-income countries (33 per 100 inhabitants), and more than twice the rate in lower-middle-income countries (63 per 100 inhabitants).[16] TVET institutions located in areas with robust digital infrastructure can more easily initiate the process of transitioning to the digital realm. However, institutions in areas with restricted Internet access, unaffordable data plans, or a lack of devices for online learning may encounter immense difficulties in adopting digital technologies, let alone implementing them fully.[17]

The ramifications of the access divide extend beyond infrastructure to significantly impact digital literacy and skill levels among populations globally, especially those in low-income countries. In this respect, the skills divide pertains to the disparities in the skills and competencies required to analyze information, create content, and enhance communication through technology.[14] Naturally, without adequate access to digital technologies and the Internet, individuals cannot develop or practice digital skills. Conversely, the skills divide can impact the access divide. Digital skills can significantly influence how effectively individuals utilize the available digital resources.[18] Even when devices or services are available, a lack of digital literacy may prevent individuals from fully utilizing these technologies, which thereby perpetuates access inequality. In the context of TVET, the skills divide is significantly apparent in the realm of teacher training and professional development. According to a survey by the UNESCO-UNEVOC International Centre for Technical and Vocational Education and Training in 2022, only 52% of TVET practitioners reported having received training on delivering TVET using non-traditional (including digital) formats.[19] This situation hinders practitioners from confidently applying digital technologies to educational settings and developing digital teaching materials for TVET programs.

The benefits divide further compounds these challenges. This divide is characterized by differences in the outcomes and advantages that individuals or groups derive from the use of digital technology.[14] This aspect of the digital divide highlights that access and skills do not uniformly translate into enhanced social and economic benefits. Individuals in more advanced areas frequently utilize technology to enhance their education, professional opportunities, and overall standard of living. In contrast, despite having Internet access, those in regions affected by the digital divide may struggle to improve their socioeconomic status due to constraints on access and digital skills.[20] In the context of TVET, the benefits divide raises concerns about the equitable distribution of returns from digital transformation. Graduates in countries with well-developed TVET systems and strong digital strategies may acquire high-demand skills that lead to well-paying jobs, whereas those in countries that are lagging may be less competitive in the global digital economy. Bridging this divide necessitates a more holistic approach to digital transformation, one that does not stop at providing infrastructure or digital skills training, but extends to ensuring that these technological gains translate into concrete improvements in learners' lives through employment or entrepreneurship.[10,21] It urges TVET institutions to collaborate with industry partners, governments, and international bodies to align their curricula with labor markets and societal needs so that all individuals can experience the full potential of digital transformation.

International cooperation for digital transformation in TVET

The significance of international cooperation in

addressing the digital divide and achieving digital prosperity for all is undeniable. The United Nations (UN) has set a clear vision for such cooperation in a number of policies.[22–24] In *Our Common Agenda*, the UN emphasizes the role of enhanced cooperation and shared responsibility in realizing a digitally inclusive future.[22] This agenda is supported by the *Roadmap for Digital Cooperation*, which outlines key directions for enhancing global digital cooperation. These strategies encompass increasing access to Internet connectivity, promoting digital public goods, enhancing digital capacity building, and establishing more efficient mechanisms for digital cooperation between different parties.[23]

Major international organizations are increasingly viewing the need for a digital transition in TVET as a priority area.[2,3,25,26] In recognition of the rapid evolution of the digital economy, such organizations have been promoting a variety of strategic approaches to integrate digital technologies and competencies into global TVET systems. Table 1 presents some recent activities by major international organizations with a focus on digital TVET and skills development. These activities include trend-mapping research, targeted training programs, digital learning platforms, international conferences, and multi-donor funding, all aiming at improving TVET outcomes and developing a digitally competent workforce. For instance, international conferences facilitate the sharing of innovative practices, strategies, and policy advocacy regarding the digital transition among TVET stakeholders. Capacity-building resources, such as digital toolkits, provide TVET stakeholders with the means to effectively integrate digital practices into their teaching and learning environments. Cross-sector partnerships play a significant role in translating digital goals into tangible outcomes, as seen in cooperative efforts between international bodies and the tech industry to facilitate hands-on digital training. Furthermore, regional-based projects underscore the importance of localized strategies that tailor digital transformation initiatives to specific needs and challenges. Through such cooperative work, these international organizations have created a vibrant community for knowledge exchange, resource mobilization, and policy development that is key to scaling up global TVET digital transformation.

Despite the broadening scope of digital-focused international cooperation in TVET, programs specifically designed to advance TVET's digital transformation are still in their nascent stages. Crucially, only a few international organizations lead these endeavors, with individual TVET institutions rarely taking the initiative. This can be attributed to the emerging nature of digital transformation practices in national TVET sectors, the historical emphasis of TVET institutions on traditional education methodologies, and TVET's typically lower status in the hierarchy of national education systems.[27–29] The latter often leads TVET institutions to prioritize their development within the national context rather than engage globally, as many of them face challenges in securing the necessary recognition and resources domestically. Additionally, constraints such as limited exposure to global trends and conservative approaches to change contribute to their reticent participation in the digital evolution of TVET on an international scale.

As such, it is important to assess how the proactive strategies of individual institutions can enrich or even catalyze the broader initiatives driving the digital transformation of TVET worldwide. An examination of the UNESCO Chair on Digitalization in TVET at SZPU can offer insights in this regard. Through a comprehensive analysis of the Chair's approaches, this study aims to delineate effective models of international cooperation by showcasing the potential for TVET institutions to transcend their traditional roles as implementers and emerge as architects of global TVET digital transformation.

RESEARCH METHOD

This study adopts a qualitative research design, specifically, the case study method, with a focus on the UNESCO Chair on Digitalization in TVET as the unit of analysis. The case study method was deemed appropriate because this technique can provide a comprehensive and in-depth inquiry into a singular phenomenon over time and within its real-life context.[30] The Chair, as introduced below, serves as an exemplary illustration of how international cooperation can be instrumental in advancing the global digital transformation of TVET.

Introducing the UNESCO Chair on Digitalization in TVET

The University Twinning and Networking (UNITWIN)/UNESCO Chairs Program was launched in 1992 by UNESCO, and it currently has a global presence comprising about 950 Chairs in 120 countries.[31] The program is designed to promote international inter-university cooperation, knowledge sharing, and collaborative work to address pressing global challenges and contribute to the development of societies.

As part of this broader initiative, UNESCO approved the establishment of the UNESCO Chair on Digitalization in TVET at SZPU in 2022, with a focus on the intersection between digital innovation and TVET. Based on the principle of "extensive consultation, joint contribution, and shared benefits", the Chair aims to

Table 1: Selected activities by key international organizations with a focus on digital TVET and skills development

Level	Organization	Name of activity	Type	Year
International	UNESCO	Enhancing TVET through Digital Transformation in Developing Countries	Report	2023
	UNESCO-UNEVOC	UNEVOC EDGE: Entrepreneurship, Digitalization, Greening and Equity	Training program	2024
	International Labour Organization	Digital Skills Campaign (with the International Telecommunication Union)	Campaign	Ongoing since 2017
	OECD	OECD Skills Outlook 2023: Skills for a Resilient Green and Digital Transition	Report	2023
	World Bank	Tertiary Education and Skills Multi-Donor Umbrella Trust Fund	Fund	2023
Regional	African Development Bank	Coding for Employment (with Microsoft)	Training platform	Ongoing since 2019
	Asian Development Bank	10th ADB International Skills Forum: A New Era of Digitalized and Climate Resilient Human and Social Development	Conference	2023
	SEAMEO VOCTECH	Learning Highlights: Digitalization and Industry 4.0 (with RECOTVET of GIZ)	Online courses	2023
	European Commission	SELFIE (Self-reflection on Effective Learning by Fostering the use of Innovative Educational technologies)	Digital toolkit	Ongoing since 2017
	CEDEFOP	Joint CEDEFOP/OECD Symposium on Apprenticeships and the Digital Transition	Conference	2023

TVET, technical and vocational education and training; UNESCO, The United Nations Educational, Scientific and Cultural Organization; UNESCO-UNEVOC, International Centre for Technical and Vocational Education and Training of UNESCO; OECD, The Organisation for Economic Cooperation and Development; SEAMEO VOCTECH, The Southeast Asian Ministers of Education Organization Regional Centre for Vocational and Technical Education and Training; RECOTVET, Regional Cooperation for TVET; GIZ, The Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH; CEDEFOP, European Centre for the Development of Vocational Training.

promote South-South cooperation, multi-partner cooperation, and capacity building on digital transformation in TVET. The Chair stands out for its strategic location in the global technology hub of Shenzhen, which allows it to draw upon a rich pool of resources and partnerships with the tech industry. The Chair has six main lines of action: (1) advancing research on the theory and practices of digital transformation in TVET; (2) developing TVET programs in the area of digital technology; (3) promoting the digital transformation of traditional TVET programs; (4) developing generic digital skills qualifications and relevant program syllabuses; (5) enhancing technology-enabled pedagogy; and (6) building digital capacity for TVET leaders and teachers worldwide.[32] The Chair's objectives are to reduce the digital divide, improve the quality and equity of TVET, and contribute to global sustainable development. In this study, the Chair's work provides a unique lens through which the dynamics of international collaboration, technological advancements, and TVET development can be examined.

The UNESCO Chair on Digitalization in TVET was selected as a case study for several reasons. Among the few UNESCO Chairs that focus specifically on TVET, including the UNESCO Chair on TVET and Sustainable Development in Qatar, the UNESCO Chair on Vocational Education in the Sphere of ICTs of Persons with Special Needs in Belarus, and the UNESCO Chair on TVET and Competence Development for the Future of Work in Germany, the Chair at SZPU distinguishes itself by its unique positioning within China's rapidly evolving TVET landscape and its emphasis on digitalization, a field in which China has made notable advancements. With over 11,000 TVET institutions and 30 million students, China has the world's largest TVET system.[33] Moreover, the country has been at the forefront of integrating digital technologies into its TVET programs by drawing upon its strengths in areas such as AI, big data, and 5G networks. The UNESCO Chair on Digitalization in TVET is therefore well-positioned to capitalize on these advantages and serve as a catalyst for international cooperation in promoting digital transformation in TVET. Furthermore, China's growing economic and technological influence on the global stage, exemplified by initiatives such as the Belt and Road Initiative, highlights the Chair's potential to make a significant impact in advancing digital skills development and knowledge sharing among TVET institutions worldwide, particularly in developing countries. In this context, the Chair's prominent emphasis on South-South cooperation and multi-partner collaboration serves as a valuable model for understanding how international partnerships can tackle the digital divide and foster fair access to TVET in developing countries. These factors collectively make the UNESCO Chair on Digitalization in TVET a highly relevant case for examining the role of international cooperation in driving TVET's digital transformation.

Case study method

The case study method was chosen because it allows for the close examination of individual instances of

phenomena in their natural settings and within a temporary boundary.[30] The present case focuses on the UNESCO Chair on Digitalization in TVET at SZPU from March 2023 to March 2024. This time frame was selected to capture the Chair's projects and activities during its first year of operation and to provide a comprehensive overview of its initial efforts in promoting digital transformation in TVET.

The data were drawn from three sources. First, data were collected from a corpus of documents, including the Chair's brochures, official website, strategy documents, project concept notes, training materials, conference proceedings, evaluation reports, and news outlets. These documents provided a detailed inventory of the Chair's key agendas, activities, and outcomes and served as a foundation for the multifaceted analysis. Second, participant observation was used as a complementary data source, with the researchers immersing themselves in the Chair's events and activities. This direct involvement provided a detailed understanding of the collaborative dynamics and internal procedures of the Chair's operations. Third, given the researchers' roles within the Chair's program, self-reflective analysis was employed adjunctly to document analysis and observation. This introspection enriched the interpretation of the Chair's initiatives and their formation.[34] While such self-examination introduces an "insider" perspective, its subjective influence on the study needs to be acknowledged.

The data analysis was guided by a thematic analysis,[35] wherein the data were carefully coded and key patterns of international cooperation identified. This systematic approach facilitated the investigation of the Chair's four main approaches to international cooperation for digital transformation in TVET, as presented in the findings.

Recognizing the limitations of the case study method is crucial for interpreting the study's findings. One such limitation concerns the singular focus on the UNESCO Chair on Digitalization in TVET, which may not capture the diverse experiences of other institutions engaged in similar digital transformation efforts. Consequently, while the study offers rich, contextual insights, the findings may have limited generalizability outside the context of this Chair. Additionally, the reliance on document analysis, observation, and self-reflective analysis without the triangulation of interviewing diverse stakeholders could introduce subjective bias. To mitigate this, the researchers engaged in regular peer debriefing and maintained reflexive journals to critically examine their interpretations and assumptions throughout the research process.

FINDINGS

The findings of this study revealed that four main approaches were applied to international cooperation by the UNESCO Chair on Digitalization in TVET, namely, (1) fostering a global dialogue on the digital transformation of TVET; (2) contributing to a digital learning community with open educational resources; (3) strengthening regional TVET capacities for digital transformation through leadership and teacher training; and (4) building a synergistic TVET ecosystem through cross-sectoral partnerships.

Fostering a global dialogue on the digital transformation of TVET

An important focus of the Chair's work in international cooperation is to promote an open and informed dialogue among global TVET leaders and professionals about effectively managing the digital shift in TVET and broader industries. This is exemplified by two annual events organized by the Chair: the Global Forum on Digital Transformation in TVET and the TVET Leadership Programme on Digital Transformation. These events provide opportunities for in-depth conversations and knowledge sharing regarding the trends and methods of digital transformation in TVET. Each event has a different focus.

The Global Forum on Digital Transformation in TVET provides a broad-based platform for global TVET leaders, industry leaders, and policymakers to engage in discussions regarding the key challenges, prospects, and best practices in TVET in light of technological advancements. In March 2023, the Chair organized the inaugural Global Forum in Shenzhen. The event brought together around 1300 TVET stakeholders from over 140 countries who participated in person or online. The attendees comprised delegates from the UNESCO Multisectoral Regional Office for East Asia, UNESCO-UNEVOC, national education authorities, TVET and higher education institutions, tech companies, and non-governmental organizations. The theme of the 2023 Global Forum was "Embracing the Digital Economy, Driving Digital Transformation". The topics of the presentations and panel discussions encompassed the Chair's mission and potential contributions to global TVET and skills systems, UNESCO-UNEVOC's toolkits and projects for the development of digital competencies, theories and practices of digital transformation in education, school-industry partnerships in ICT training and certification, and TVET institutional strategies for digital transformation. Feedback from the Forum highlighted its notable contribution to expanding collaborative networks among TVET stakeholders, which led to the initiation of several cross-border projects focused on expediting digital skills development and curricular innovation.

The TVET Leadership Programme on Digital Transformation focuses on capacity building for TVET leaders, who are the agents of change in their

institutions. It aims to provide these actors with the necessary knowledge and strategies to initiate or improve digital transformation processes within their institutions. In November 2023, the Chair held the first TVET Leadership Programme in Shenzhen, and 23 TVET leaders and professionals from 17 countries in Africa, Asia, and Oceania participated. The six-day event included seminars delivered by experts, as well as visits to SZPU's training centers and a global high-tech company located in Shenzhen. These activities focused on different topics, including global strategies for digital transformation in TVET, technological innovation and institutional strategies, digital application scenarios in TVET, public-private partnerships for TVET digital transformation, and the development of digital learning resources. Moreover, the Programme offered an interactive platform to allow the exchange of insights and best practices between different institutions and to foster a greater understanding and appreciation of different cultures through diverse perspectives. At the end of the Programme, the participants reported a notable increase in their understanding of and confidence in managing digital transformation within their institutions.

Despite these achievements, challenges remain in ensuring equitable access and inclusion in the digital transformation process. To some extent, the varying levels of digital readiness and infrastructure in different institutions and countries hampered effective communication, leading to disparities in participation and implementation of the discussed strategies. Additionally, language barriers and differing time zones complicated synchronous communication and engagement among the international participants.

Contributing to a digital learning community with open educational resources

UNESCO places a strong emphasis on the dissemination of open educational resources (OERs) to ensure inclusive and equitable quality education while promoting lifelong learning opportunities for all.[36] In line with this objective, the Chair has actively curated and provided a variety of ICT-related OERs on its online platform.[37] All these resources have been translated from Chinese into English to cater to a global audience.

One type of OER provided on the Chair's platform consists of online courses on digital technology. The subject areas include programming, virtual and augmented reality, cloud computing, AI, data science, new energy vehicles, and network technology (Table 2). Designed to cater to learners from diverse countries and with differing technological backgrounds, these courses facilitate the acquisition of foundational knowledge as well as insights into cutting-edge technological innovations. This approach ensures that the content is accessible to beginners yet rich and stimulating enough to engage those seeking to deepen their understanding of the latest digital trends and applications. Additionally, the Chair offers courses through the International Institute of Online Education, a public digital learning platform that provides free, high-quality ICT courses. These courses primarily target teachers at higher education institutions, thereby broadening the Chair's reach and impact.

A further type of OER available on the Chair's platform is a compilation of the syllabuses of 28 TVET programs, all of which focus on digital technologies (Table 3). These programs are categorized into five clusters: ICT and Electronic Engineering, AI, Mechatronics, New Energy Vehicles, and Digital Media Arts. Each program's syllabus offers detailed information about the industry and occupations that the program is designed for, the competencies, knowledge, and skills that students are expected to acquire, the curriculum structure, the requirements for the program leaders and instructors, the infrastructure needed for practical training, and the quality assurance system. These syllabuses can provide a comprehensive framework for TVET institutions seeking to implement or improve their digital technology programs that resonate with current industry standards and skill demands.

A third type of OER prepared by the Chair comprises two comprehensive programs, namely, AI Technology Service and Big Data Technology and Application, which together include a total of 50 courses. The AI Technology Service curriculum features 26 courses, which cover a broad spectrum of AI-related knowledge and skills, while the Big Data Technology and Application curriculum offers 24 courses, which provide a well-rounded foundation in big data analysis, manipulation, and application. Each course of the curricula is designed with a holistic approach that incorporates a detailed course description, learning objectives, course design, content and requirements, and implementation plans. These resources are instrumental in guiding TVET teachers through the course development process and ensuring that the delivery of content is well-structured and pedagogically sound. By laying out clear curricular pathways, the Chair aids in the systematic digital upskilling of the TVET sector.

The Chair has also compiled approximately 100 cases of "promising practices" in digital transformation from SZPU and its partner institutions. These cases demonstrate the breadth of digital innovation in various TVET programs, curricula, and training scenarios, as well as the use of digital technologies and platforms to support teaching, learning, and administrative management. In addition to comprehensive

Table 2: List of online courses (as of March 2024)

Schools/Centers	Online courses
School of Artificial Intelligence	Network Operating System (Linux) Augmented Reality Engine Development Introduction to Cloud Computing Data Acquisition Technology Object Oriented Programming in Java Mini Program Design and Development Application of Cloud Artificial Intelligence Big Data and Artificial Intelligence Introduction to Artificial Intelligence
School of Mechanical and Electrical Engineering	3D Printing Technology
School of Automotive and Transportation Engineering	Introduction to New Energy Vehicles
Center for Educational Technology and Information	Augmented Reality Technology
Industrial Training Center	Electrician Technology and Practical Training
School of Electronic and Communication Engineering	RedHat System Certification Routing and Switching

Table 3: List of programs in the program syllabuses (as of March 2024)

TVET program clusters	Program names
ICT and Electronic Engineering	Electronic Information and Engineering Technology Mobile Internet Application Technology Internet of Things Application Technology Computer Network Technology Information Security and Management Communication Technology
Artificial Intelligence	Artificial Intelligence Technology Service Computer Application Technology Software Technology Cloud Computing Technology and Application Big Data Technology and Application Virtual Reality Application Technology
Mechatronics	Intelligent Building Engineering Technology Mechanical Design and Manufacturing Mechatronics Technology Electrical Automation Technology Intelligent Control Technology Industrial Robot Technology
New Energy Vehicles	Automobile Electronic Technology New Energy Vehicle Technology Intelligent Transportation Technology Application Automobile Application and Maintenance Technique Operation and Management of Urban Rail Transit
Digital Media Arts	Animation Production Technology Digital Media Art Design Animation Design Game Art Design Radio, Film, and TV Production

ICT, information and communication technology.

documentation on the background, purpose, and objectives of the digital transformation project, each case provides the tools and methods used for its implementation. It also highlights the achieved outcomes and the potential for transferability to other contexts. Similar to UNESCO-UNEVOC's database of "Innovative and Promising Practices" in TVET,[38] the cases of digital transformation provided by the Chair serve as a repository of knowledge and inspiration for the global TVET community. They demonstrate the use of digital technologies to improve educational delivery and operational efficiency in real-world settings, which can benefit TVET teachers, trainers from a wide range of disciplines, and administrators.

While providing these multifaceted OER offerings enriches the international digital learning community, it is important to acknowledge their limitations. Currently, there is insufficient data to comprehensively evaluate the reach and utilization of these materials, or to gauge the uptake of open-access courses by various TVET learners and providers. Future efforts should focus on collecting

and analyzing such data to establish indicators of impact, which can inform strategies for enhancing the dissemination and application of these resources. Moreover, challenges remain in ensuring the broad relevance and accessibility of the OERs. Adapting OERs to diverse languages and educational contexts is complex and may hinder their universal effectiveness. The digital divide remains a concern, as not all target beneficiaries have equal access to the Internet or the devices needed to utilize OERs effectively. Overcoming these obstacles is essential for fully realizing the potential of OERs in advancing digital competencies across all TVET institutions.

Strengthening regional TVET capacities for digital transformation through leadership and teacher training

Given the contemporary need to adapt to rapid technological advancements, UNESCO has prioritized digital capacity building as a key strategy for enhancing the quality and relevance of TVET systems.[1,17] Its importance is magnified in developing countries, where access to technology and digital skills training is often limited. As a result, the Chair has designed capacity-building projects aimed at strengthening the skills, knowledge, and competencies of TVET leaders, educators, and administrators in developing countries to enable them to effectively implement digital technologies within their respective areas.

As previously mentioned, the TVET Leadership Programme on Digital Transformation specifically targets leaders from developing countries, with the goal of equipping them with the necessary expertise to drive digital transformation within their institutions. Another project focusing on TVET leaders was the China-Germany-Mongolia-UNESCO Joint TVET Leadership Seminar on Digital and Green Transitions, which took place in April 2023. The two-day online seminar was co-organized by the UNESCO Chair on Digitalization in TVET, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in Germany, the Vocational Education Training Partnership in Mongolia, and the UNESCO Multi-Sectoral Regional Office for East Asia. This multilateral cooperative project helped bolster the digital and green skills of TVET leaders in Mongolia. Approximately 200 leaders from over 70 Mongolian TVET institutions attended the seminar. The focus on digital transformation and green transition, which are particularly relevant to Mongolia's expanding digital economy and its commitment to environmental sustainability, reflects a broader global trend toward integrating these crucial areas into TVET systems. The inclusion of expert presentations from prestigious TVET institutions and professional bodies from China, Germany, Mongolia, and UNESCO provided the attendees with rich and diverse insights and practices. This collaboration laid the groundwork for implementing innovative digital and green initiatives in Mongolia's TVET sector, as well as for further international TVET cooperation aimed at sustainable digital transformation.

Furthermore, the Chair broadened the scope of its capacity-building projects to include a wider range of TVET professionals. For instance, the Chair's team at the UNEVOC Centre of SZPU organized the UNEVOC Network Co-Action Initiative 2023, a project launched by UNESCO-UNEVOC. With the theme "Building Digital Transformation Capacity in TVET", the Co-Action Initiative represented another significant endeavor in TVET capacity building for digital transformation. The project consisted of four online workshops over two months and reached a wide audience, which included leaders, teachers, trainers, and administrators from six countries in the Asia-Pacific region. Experts from various fields and professions discussed a range of topics, such as skills forecasting, ICT talent ecosystem building, the design of AI programs, the transformation of traditional automotive programs, and the implementation of digital learning technologies and pedagogies. The webinar participants reported high levels of satisfaction, with an average rating of 4.8 out of 5.0. They expressed a keen interest in obtaining policy insights on digital transformation and the use of emerging technologies in teaching, training, and management. The participants also offered suggestions for improving future webinars, such as increasing interactivity on the online platform. In addition, the Chair offered training courses on TVET digital transformation for leaders and educators from TVET institutions in Cambodia, Peru, Côte d'Ivoire, and Gabon.

Reflections on past projects highlighted the critical importance of adaptability to allow for the nuanced tailoring of content and teaching approaches to the specific educational, cultural, and technological contexts of different regions. Similarly, scalability is pertinent, as it ensures that successful methods and practices deployed in one context can be expanded to others. Balancing these dynamics—adapting to particular needs while seeking ways to scale the impact—remains a key consideration in the deployment of effective capacity-building projects.

Building a synergistic TVET ecosystem through cross-sectoral partnerships

The concept of an "ecosystem" characterized by the dynamic interplay between diverse stakeholders is fundamental to the digital transformation within TVET.[39–41] A synergistic TVET ecosystem that involves

the private sector, governments, and international educational communities can help address any skills mismatch, create customized programs, and amplify policy support and investment.[42] Positioned at the nexus of the ecosystem, the Chair has maintained a concerted approach to TVET digital transformation by forging strong partnerships with the technology sector, national and regional education authorities, international organizations, and peer institutions worldwide.

SZPU, the host institution of the Chair, is known for its strength in school-industry collaboration in China's TVET landscape. It has maintained close partnerships with global industry leaders, such as Huawei, BYD Auto, and DJI, in the co-development of programs, courses, qualifications, learning platforms, training models, and leading initiatives in research and innovation. Building on this collaborative foundation, the Chair has continued to expand partnerships with Chinese high-tech companies that operate globally, particularly those based in developing countries. Areas of collaboration include specific capacity-building projects on TVET digital transformation in these countries, the development of transnational digital skills qualifications, and improvements in TVET programs to match the skills supply with the demands of the local and global labor markets. The Chair's approach not only fosters mutually beneficial relationships with the partner companies but also ensures that these partnerships contribute to the TVET and skills systems of the countries involved.

National and regional education authorities, alongside international organizations, are integral to the Chair's strategy for cultivating a well-coordinated TVET ecosystem. In June 2023, the Chair and the UNESCO Regional Office in Bangkok co-organized the Launch Meeting of the Study on the Use of Digital Technologies in Post-Secondary TVET Institutions in the Association of Southeast Asian Nations (ASEAN)+3 Countries, serving as a prime demonstration of this collaborative articulation. This event epitomized cross-regional collaboration by assembling educational officials and TVET experts from UNESCO Bangkok, the Southeast Asian Ministries of Education Organization, the Ministry of Education of China, and diverse TVET institutions from ASEAN countries, as well as China, Japan, and South Korea. The participants engaged in discussions about leveraging digital technologies to enhance the capabilities of TVET teachers and accelerating the digital transformation of TVET systems across East and Southeast Asia. By convening participants from a myriad of educational ministries and organizations, the Chair highlighted the necessity of policy dialogue and collective thinking about innovative ways to empower TVET teachers with digital tools and training, thereby shaping a positive trajectory for the digital transformation of TVET in the region.

The Chair places a strong emphasis on fostering partnerships with peer TVET institutions worldwide. This is done in two ways: conventional inter-institutional partnerships and engagement within the global network of TVET institutions. The Chair has established close relationships with TVET institutions in several countries with the aim of exchanging knowledge and facilitating the digital competence development of TVET leaders and teachers. Concurrently, the Chair plays a proactive role within the global TVET community, particularly through its participation in the UNESCO-UNEVOC Network. A notable endeavor in this context is the Chair's involvement in the Bridging Innovation and Learning in TVET (BILT) project, which was implemented by UNESCO-UNEVOC. The BILT project is guided by the overarching theme of new qualifications and competencies in TVET and has "digitalization" as one of its core thematic areas—a focus that corresponds clearly with the Chair's mission. The Chair's team has been engaged in the development of the BILT project's Self-Reflection Tool (SRT), which is designed to help TVET providers identify emerging qualifications and competencies, integrate them into curricula, and implement innovative training approaches. SZPU was selected as one of the three "coach institutions" for the project and has been tasked with disseminating the updated SRT methodology to other TVET institutions in the wider region.[43] The Chair can therefore assist peer TVET institutions in adopting and adapting new qualifications and competencies that are essential for navigating the fast-changing world of work.

While these partnerships signify substantial progress in fostering a dynamic TVET ecosystem, several challenges persist. Key among them is aligning the goals and expectations of the various stakeholders within the ecosystem, including industry partners, educational institutions, and policymakers. It is not easy to establish smooth communication and collaboration mechanisms among diverse entities, as each has its unique processes and priorities. Furthermore, ensuring equitable participation and tangible benefits for all partners, especially those from under-resourced regions, presents an ongoing challenge. Addressing these issues is vital for building a synergistic TVET ecosystem and ensuring the long-term success of these partnerships.

DISCUSSION

Based on the findings, this section provides a synthesized analysis of the international cooperation

approaches adopted by the UNESCO Chair on Digitalization in TVET for advancing digital transformation. This analysis addresses five dimensions: the content of cooperation, the participants in cooperation, the aim of cooperation, the means of cooperation, and the support system in place.

In terms of the content of cooperation, the Chair has made digital transformation in TVET the central focus of its collaborative initiatives. It therefore differentiates itself from mainstream international cooperation endeavors in TVET, which often emphasize broader themes such as access, quality, and relevance.[44] By focusing specifically on digital transformation, the Chair addresses a critical need in the TVET sector, which stems from the rapid pace of technological changes and the growing demand for digital skills in the workforce. This focused approach recognizes the transformative potential of digital technologies in TVET, as well as the importance of international cooperation in addressing the digital divide and other global challenges.

The participants in cooperation concentrate on TVET leaders and professionals from developing countries. This selection reflects the Chair's commitment to diversity and inclusivity within the broader educational development agenda. By actively involving stakeholders from regions that are often underrepresented in global discussions on TVET, the Chair promotes a more equitable and representative dialogue. This inclusive approach enriches the knowledge base by incorporating diverse perspectives and experiences. It also helps ensure that the developed strategies and solutions are relevant and applicable to the specific contexts of developing countries. Moreover, by empowering TVET leaders and professionals from these regions to take an active role in shaping the digital transformation agenda, the Chair contributes to building local capacity and fostering a sense of ownership and sustainability.

The primary aim of cooperation is to enhance the digital capacity of TVET leaders and teachers in the participating institutions, recognizing the critical role they play in driving educational change and innovation. This means equipping TVET leaders and teachers with the necessary digital competencies, pedagogical skills, and change management abilities to effectively integrate digital technologies into their work. Through targeted leadership programs and teacher training workshops, the Chair's international cooperation projects prioritize the digital upskilling of these key change agents, thus contributing to creating a digitally literate and capable community of educators who can drive the transformation of TVET institutions from within. This approach can greatly benefit developing countries, which may have limited access to professional development opportunities and global best practices.

The means of cooperation adopted by the Chair feature the strategic employment of multiple digital tools, including online learning platforms, virtual conferences, and digital resource repositories, which expand the reach and accessibility of its collaborative initiatives. For instance, the use of online learning platforms and virtual conferences allows for a wider range of stakeholders to participate, regardless of their geographic location or financial constraints. Similarly, offering OERs through digital repositories promotes the democratization of knowledge and facilitates the dissemination of best practices and innovations in TVET digital transformation. These digitally enabled means of cooperation exemplify the Chair's commitment to practicing what it preaches and demonstrate the transformative potential of digital technologies in enhancing international collaboration.

The support system of cooperation involves engaging a range of stakeholder groups within the TVET ecosystem, including industry partners, governmental bodies, international organizations, and peer TVET institutions. This multi-stakeholder approach recognizes the complex and interdependent nature of TVET systems and the need for coordinated action across different sectors to achieve digital transformation goals. By forging partnerships with industry actors, the Chair ensures that its initiatives align with the contemporary skill needs of the labor market. Collaboration with governmental bodies and international organizations helps create an enabling policy environment and mobilizes resources to support digital transformation efforts. Finally, peer-to-peer cooperation among TVET institutions promotes the exchange of experiences, challenges, and solutions, as well as the development of a global community of practice in TVET digital transformation.

To measure the impact and evaluate the progress of its international initiatives and collaboration, the Chair follows the monitoring and evaluation framework set by UNESCO. As part of this framework, the Chair submits annual progress reports to the National Commission of the People's Republic of China for UNESCO, in which the Chair documents its activities, partnerships, and outcomes. A comprehensive progress report will be submitted to UNESCO at the end of the initial four-year period, at which time the renewal of the Chair will be determined based on its performance and achievements. This report will detail the Chair's key educational and training programs, research undertaken, conferences and meetings organized, partnerships and exchanges, and cooperation with UNESCO entities. This systematic

reporting process not only allows for regular monitoring of the Chair's progress but also enables it to assess its impact and make data-driven decisions for future planning.

While the Chair's international cooperation approaches demonstrate significant potential for advancing TVET's digital transformation, they are not without limitations. One is the possibility of uneven participation and benefits across different regions and institutions. Despite the Chair's efforts to promote inclusivity and diversity, the digital divide and resource constraints continue to hinder the full participation of some TVET institutions, particularly those in the least developed countries. Another challenge is ensuring the sustainability and long-term impact of the initiatives. Capacity-building efforts, for instance, require ongoing support and follow-up to transform the acquired knowledge and skills into tangible institutional changes. Similarly, the success of collaborative projects and partnerships depends on the continued engagement and commitment of all the stakeholders involved. To address these challenges, the Chair may need to further strengthen its monitoring and evaluation mechanisms by moving beyond output-based reporting to more rigorous impact assessments that can capture the long-term effects of its initiatives at individual, institutional, and systemic levels.

Furthermore, the Chair's focus on digital transformation in TVET, while crucial, represents just one aspect of the broader TVET development agenda. To achieve truly inclusive and sustainable TVET systems, digital transformation efforts must integrate with other priorities, such as the green transition, equity and inclusion, gender equality, and lifelong learning.[2] In this regard, the Chair could seek to collaborate more closely with other UNESCO TVET initiatives and international partners working on complementary themes to develop more holistic and integrated approaches to TVET elevation.

CONCLUSION

This study contributes to the emerging knowledge base on international cooperation for digital transformation in TVET through an in-depth case study of the UNESCO Chair on Digitalization in TVET. While major international organizations are leading most existing initiatives on TVET digital transformation, this study highlights the proactive strategies that individual TVET institutions can adopt to promote digital transformation through international partnerships and platforms. It demonstrates the potential for TVET institutions to transcend their traditional roles as implementers and emerge as architects of digital change, thereby enriching the scholarly understanding of their evolving roles and capacities.

Given the early stages of the current initiatives aimed at enhancing digital transformation in TVET, there is a limited understanding of how to design and implement such international projects effectively. By providing a comprehensive analysis of the Chair's key projects and activities over a one-year period, this study offers a detailed account of the various approaches employed, the challenges encountered, and the lessons learned. These findings provide valuable insights to inform the strategies of other TVET institutions that are seeking to leverage international cooperation to advance digital transformation.

As the digital economy continues to evolve, it is crucial for TVET stakeholders to further explore innovative approaches to collaboration that can bridge the digital divide and ensure equitable access to the benefits of digital transformation. The digital divide is a complex and multifaceted issue that concerns disparities in access to technology, digital skills, and the benefits of using digital technology. Addressing these challenges requires a comprehensive approach that considers the specific needs and contexts of different regions and populations. Future research could examine a broader range of international cooperation initiatives and identify the key factors that enable or hinder their success in promoting digital transformation in diverse settings. This could include comparative studies of different international cooperation models and case studies of successful initiatives that have effectively fostered collaboration among TVET institutions in different contexts.

Similarly, while exploring how international cooperation can advance digital transformation in TVET, it is equally valuable to investigate how digital technologies can enhance and facilitate international cooperation. Research on the utilization of digital platforms, virtual collaboration tools, and other technological solutions to support cross-border partnerships and capacity building could provide valuable insights for optimizing international cooperation methods in the digital age. By integrating digital technologies into international cooperation efforts, TVET stakeholders can work toward increasing their effectiveness and outcomes, strengthening their roles in promoting inclusion and innovation, and ultimately contributing to the sustainability and resilience of TVET systems.

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