Education 2030 - Achievements of TVET in Asia and The Pacific along with The Fourth Industrial Revolution

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Abstract

The modernization of TVET has not occurred with a system-wide approach covering the entire spectrum of TVET institutes worldwide. The literature that incorporates the Sustainable Development Goal for Education (SDG4) and the fourth industrial revolution in TVET is very rare to be found from international and comparative standpoints since these areas are still emerging. Further, case-based or single country-based experiences do not provide sufficient information to make informed decisions. Therefore, more empirical studies are needed on the adoption of SDG4 in TVET institutes to gain a broad-based understanding of the prevailing context. Given these gaps in the scholarship, the present study investigated the status of the adoption of SDG4 in TVET institutes. Accordingly, the study collected data covering the areas of 1) the teaching and learning context, 2) steps taken to impart skills for employment, and 3) steps taken to enhance the capacities of staff in response to the changing world of work from fifteen Asian and Pacific countries. Four hundred and twenty-eight TVET staff responded to the survey. The findings showed significant differences by the regional classification of the country and by the type of TVET institute. The findings of the study are novel and provide ample evidence for the status of TVET in incorporating SDG4 in the fourth industrial revolution era. The findings also showed that the policymaking bodies must take active measures to increase responsiveness in fulfilling SDG4 and addressing challenges brought about by the fourth industrial revolution technologies.

1. Introduction

Sustainable Development Goals of the United Nations (SDGs) establish a development agenda applicable across countries. Goal four (or SDG4) is for education worldwide, which is identified as 'Education 2030'. The present study was conducted on tertiary education with reference to TVET. The main rationale underlying TVET is to produce a skilled workforce required for a country's economic and social development through an overall lifelong learning agenda (Allais & Wedekind, 2020; Ling, 2015). Hence, TVET institutes should deliver SDG4 targets relevant to them.

When framing teaching and learning within the agenda of SDG4, attention must be paid to the technological context attributed to the fourth industrial revolution (4IR). The changes occurring as a result of 4IR inevitably insist on incorporating digital technologies into the curricula. As such, education institutes need to cultivate a set of dynamic capabilities to respond to changes brought about by 4IR. With specific reference to TVET, on the one

hand, institutes should incorporate 4IR technologies into the existing curricula and introduce new programmes by tracking new vocations and professions as and when these emerge across economic sectors. With the changes in technologies, TVET should cover not only monolithic programmes but also microlearning modules for employees to return to institutes to fill their skill gaps while benefiting new technologies that allow them to participate in distance or hybrid modes of delivery (ILO, 2020). If TVET fails to prepare students with appropriate programmes, the labour market at vocational levels may experience shortages and surpluses in skill requirements (Darvas & Palmer, 2014). The successful identification of changes in vocations and professions can be accomplished only through close relationships with industry partners and accreditation bodies. Hence, TVET institutes should develop a collaboration system with a multistakeholder approach to increase responsiveness to labour market needs (Ilori & Ajagunna, 2020). On the other hand, teaching, teaching support, technical, and administrative staff, identified under the umbrella of 'TVET teachers' (ILO, 2020, p.60), should have appropriate capabilities to incorporate new technologies into teaching and learning. Further, ILO (2020) showed a direct link between the digital competence of teachers and the institute's innovative capabilities and emphasized the importance of teacher development with a digital-first mindset. Hence, demands led by SDG4 and 4IR technologies are very much applicable and should urgently be addressed by all education systems worldwide. Although the adoption of digital technologies is identified as a key factor in the digitalization of pedagogies, like all other higher education institutes, TVET institutes also find difficulties in responding to the rapid pace at which technological changes are happening in the world (Goger et al., 2022). The response of TVET institutes to the changing nature of the employment landscape is insufficient and slow-paced; there are lapses in making appropriate structural changes within TVET institutes (Rotatori et al., 2021).

Further, the modernization of TVET has not occurred with a system-wide approach covering the entire spectrum of TVET institutes (Schröder, 2019; Spöttl and Windelband, 2021). As reviewed in the next section on literature review, previous studies such as Spöttl and Windelband (2021) provide evidence to suggest that TEVT's response could differ by the type of institutes – technical and vocational universities, polytechnics, and colleges while Schröder (2019) provides evidence to suggests that TEVT's response could differ by the regional classification of the country. Hence, it is important to understand differences in TVET in addressing SDG4 and 4IR competencies. However, on the one hand, the literature that incorporates SDG4 and 4IR in TVET is very rare to be found from international and comparative standpoints since these areas are still emerging. On the other hand, case-based or single country-based experiences do not provide sufficient information for academics, practitioners, and policymakers to make informed decisions on such differences. Given these gaps in the scholarship, it remains essential to investigate the status of TVET in Asia and the Pacific. Accordingly, the present study proposes that differences could be reflected in the implementation of SDG4 and addressing 4IR competencies by respective institutes and geographic locations of the countries.

Building on the above-mentioned developments with respect to education and training as well as the importance of addressing the existing research gap in the literature, the present study investigated 1) the teaching and learning context, 2) steps taken to impart skills for employment, and 3) steps taken to enhance the capacities of staff in TVET institutes attached to tertiary-level STEM programme offerings. As discussed in detail in the latter parts of this article, the present study investigated three SDG4 targets commonly identified as 4.3, 4.4, and 4.c since these are the most related to TVET on its priorities and commitments to education (UNESCO, n.d.). In brief, target 4.3 in the context of TVET ensures that adults have access to quality education; target 4.4 ensures adults possess skills linked to work; target 4c ensures the supply of qualified teachers. As reviewed in depth in the next section, the first objective addresses the targets 4.3 and 4.4; the second objective addresses the specific aspect of target 4.4, i.e., skills for work; the third objective addresses 4.c. As detailed in the section on methodology, fifteen Asian and Pacific countries were included in the study, from which four hundred and twenty-eight TVET staff responded to the survey. Based on the review of literature in the next section, we propose that differences can be found across countries by the TVET institute type and the regional classification of the country.

When considering the study's significance, the developments due to 4IR are primarily characterized by digitalization. The emergence of 4IR technologies created an opportunity to introduce a new learning environment, which is more active, collaborative, and personalized while addressing 4IR technologies in the subject content. Like other higher education systems, TVET should inevitably move towards 4IR technologies. When summarizing the key points of the findings of our study, we showed how the labour market and education system are drastically affected as consequences of SDG4 in preparing TVET for 4IR. Our study also showed the importance of learning to function with 4IR technologies at work, learning new 4IR technologies to effectively learn subject content, reskilling and upskilling with a continuous learning perspective as well as increasing the accessibility, flexibility, and quality of education as main insurgencies due to the emergence of 4IR technologies.

2. Literature Review

2.1 United Nations Sustainable Development Goal 4 – Education 2030

SDG4 covers 'inclusive and equitable quality education and the promotion of lifelong learning opportunities for all citizens' (The United Nations, n.d.). In succinct, SDG4 is a very important goal since it has connections to a few other SDGs, such as SDG3 on 'health and well-being', SDG5 on 'gender equality', and SDG8 on 'decent work' (Nilsson et al., 2016). Hence, it is implied that effective implementation of SDG4 leads to tackling a broad range of challenges in the economic, social, and environmental spheres (Furguson, 2020). Although the successful implementation of SDG4 targets depends on multiple stakeholders, all higher education institutes must take their assigned role in the implementation of SDG4 (Leal Filho et al., 2019). As a part of the higher education system, SDG4 made an explicit inclusion of TVET, a sector that is generally excluded from discourse on higher education (Ling, 2015). Hence, on the one hand, scholars identify this inclusion itself as an achievement because countries must include TVET in their national-level policy agendas and implementation plans (Allais & Wedekind, 2020). On the other hand, scholars identify this inclusion as a recognition of its potential role in achieving equitable and sustainable development in economic, social, and environmental spheres yielding better outcomes for individuals and communities (Allais & Wedekind, 2020; Furguson, 2020). Therefore, TVET institutes must take a leading role in accomplishing the targets relevant to them in the Education 2030 agenda.

SDG4 has 10 targets, of which seven are on expected outcomes (targets 4.1 to 4.7) and three are on the means of achieving these seven targets (4.a to 4.c). The present study investigated the adoption of three SDG4 targets, i.e., 4.3, 4.4, and 4.c, since these are the most related to TVET (for more refer to UNESCO, n.d.). These targets, in brief, are as follows.

- Target 4.3 is on 'quality technical and vocational education', and states 'By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university' (UNESCO, n.d.)
- Target 4.4 is on 'youth and adults having relevant technical and vocational skills for employment, decent jobs and entrepreneurship', and states 'By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs, and entrepreneurship' (UNESCO, n.d.)
- Target 4.c is on 'the supply of qualified teachers', and states 'By 2030, substantially increase the supply of qualified teachers, including through international cooperation for teacher training in developing countries, especially least developed countries and small island developing States' (UNESCO, n.d.).

When these three targets are matched with the objectives of the present study, the first objective addresses target 4.3; the second objective addresses the specific area of target 4.4 'skills for work'; the third objective addresses target 4.c.

With regard to the achievements of the Education 2030 agenda, Klees (2024) and Leal Filho et al. (2019) suggest that although SDG4 was first introduced in 2015, higher education institutes are still in the infancy of implementation. In this context, Klees (2024) highlights the need to understand 'where we are' when aspiring to achieve SDG4. Hence, Allais and Wedekind (2020) state the importance of understanding the extent to which policies are in place to develop the TVET institutes in their full complexity. In this regard, contextual elements such as the type of TVET institute and/or the regional classification of the country could play a bigger role in policy priorities (for more refer to Allais & Wedekind, 2020). This justifies our study's argument that TVET offerings could differ in terms of the relative importance given by respective institutes and geographic locations of the countries. The present study, with its objectives, presents the findings from the global South, which is often missing from global discourse.

2.2 Economics of Education and Education Production

From the economic standpoint, competent manpower yields several benefits to a country as well as the personnel concerned. From the country's standpoint, the availability of skilled manpower generates competitive advantages allowing it to adopt new technologies and modernize service/industrial sectors. Hence, skilled manpower is an important part of the total human capital stock of the country. From a skilled individual's standpoint, in-demand skills increase the chances of securing better employment, higher salaries, future employability, and overall family wealth (Puwakgahawela et al., 2023; Rosmiler & Geske, 1977). Hence, countries as well as individuals or their families expect considerable returns from the investment in education.

When considering education production, bachelor's degrees from universities are the most attractive for elite and white-collar positions. However, of the working-age population of a country, a minority secures university degrees (Ling, 2015). Although TVET is considered an inferior system compared to the conventional university system, a large portion of a country's working-age population ends up obtaining TVET qualifications

(Ling, 2015; Naziz, 2019). Still, these individuals occupy low and middle-level skilled/sub-professional positions in the vital sectors of the economy (Jabarullah & Hussain, 2019). In other words, the effect on TVET and its contributions to the labour market is more explicit than any other higher education institute in the education sector of a country, such as a university. Hence, TVET institutes should produce competent trainees with sound theoretical knowledge and practice for immediate skill application from day one of employment. Furthermore, when the right skills are imparted, working adults with TVET qualifications can move across borders for employment as well as migration. This demands creating a uniform TVET system that is on par with other countries in producing a skilled workforce with accredited credentials. However, such demands have an enormous influence on how TVET operates, globally. Considering the importance, international bodies such as the World Bank and ILO encourage countries to establish a universal system for TVET (The World Bank Group, 2021; ILO, 2020).

When considering TVET as a system of education production, like in K-12 and conventional university education systems, its inputs in producing an able workforce are teaching staff, curricula, laboratories, and all other resources that represent characteristics of education production. Conversely, its outputs are the graduates or passed-out trainees with market-relevant capabilities (Brewer et al., 2010). However, TEVT education production is different to K-12 as well as conventional universities such that TVET should give priority to both theory and hands-on practical skills (Gonçalves, 2019; Naziz, 2019). As such, from the input side, TEVT should have higher levels of labour market-friendly laboratories, equipment, and curricula as well as competent teachers who are versatile with the newest technologies.

The pedagogical approach of TVET relies on theory, practice, and workplace learning. Specifically, students learn theorerical pronciples at classrooms of TVET institutes, practice at workshops of TVET institutes, and master skills while on apprenticeship at industry partners. 4IR is having an extensive effect on TVET inputs. With the 4IR, inevitably, subject content and delivery should be modernized. From the output side, TVET should produce skilled trainees who should possess appropriate and relevant skills for the profession trained to successfully transfer the skills learned from day one of employment. The Sections to follow in this article review the literature within the scope of the present study.

2.3 Curricula and Training Content

Two of the core functions of TVET are designing and developing curricula and educational/training material (The World Bank Group, 2021). The first covers the areas of mapping the curriculum; the second covers the areas of creating teaching and learning material with the use of appropriate media. With 4IR, TVET institutes must respond to requirements of emerging vocations and professions as well as changing competence requirements of the existing vocations and professions, i.e., new education and training content is emerging. In addition, due to 4IR technologies, the way of delivery of subject content is also changing. This is especially true for technology-oriented STEM fields (Ilori & Ajagunna, 2020). Effective delivery of subject content demand the use of digital technologies (ILO, 2020; Paton et al., 2018). The adoption of digital technologies helps to reduce the boundary between theory and practice and makes learning more interactive and real-time. Support mechanisms are decisive in the adoption of andragogical and heutagogical teaching and learning practices. The main support mechanisms can be identified as financial support, infrastructure availability, and the preparation of teachers for digital delivery. When support for the above is inadequate, TVET institutes could find difficulties in moving to andragogical and heutagogical learning practices (refer to Halupa, 2015).

If TVET institutes fail to design, develop, and implement a skill acquisition-based curriculum, their programme offerings may encounter problems relating to quality, relevance, and flexibility (Chakroun, 2019); graduates may fail to secure employment for not having the required skills for employment (Ilori & Ajagunna, 2020). In this regard, 4IR technologies have the potential to recuperate labour market matching by co-developing training content with employers, which leads to an increase in the relevance of the skills attained enhancing the quality and relevance of programme offerings (The World Bank Group, 2021). With regard to flexibility in the education provision, access to programme offerings in a lifelong learning agenda is a key consideration. 4IR technologies can improve access. For example, online learning can reduce the marginal costs of education provision, appeal to low-income strata of society with reduced education provision costs, reduce geographical distance, and offer flexible learning options for working adults and adults with family responsibilities.

2.4 Skills for Employment

Another core function of TVET is preparing students for effective participation in the labour market. Beginners get their initial skill sets from TEVT institutes by following foundation programmes, which help them to participate in the labour market (Fernando & Wickramasinghe, 2024). The technological advances with 4IR demand continuing education, i.e., retraining. The need for retraining will bring them back to TVET institutes for reskilling or upskilling programmes for their skill adaptability (ILO, 2020; Ivaldi et al., 2022). Reskilling or

upskilling programmes allow an individual to learn new skills so that he/she can do a different job or can do the same job differently (Ivaldi et al., 2022).

When reskilling and upskilling as well as flexible learning opportunities are concerned, micro-learning, digital credentials, and recognition of prior learning are important. 4IR technologies have opened new avenues for formally recognising prior micro-learning by way of micro-credentials, which allow the transfer of credits across educational and professional institutes (Goger et al., 2022). This requires TVET institutes, or rather the higher education system of a country, to move out of the traditional framework with rigid course structures and accept the fact that many youths and adults in the 4IR era may not opt to move sequentially along an unbroken timeline from one level to another to acquire learning, i.e., primary to secondary to tertiary education. The required transformations can be broken down into three areas – a) the programmes of short duration should be offered and recognized in micro-credentials, b) micro-credentials are verified and signalled electronically for those who successfully complete micro-learning, c) provisions to accumulate and stack together micro-credentials to form a credit course, d) the provision to transfer digital micro-credentials across higher educational/professional institutes to pursue further academic/professional learning. Above (d) is possible only if digital credentials are a part of the national qualification framework of a country. The World Bank Group (2021, p.95) provides evidence for Sri Lanka's National Skills Passport (NSP). This is the country's central web-based online database to recognize skilled workmanship through National Vocational Qualification (NVQ) and verify related work experience. According to the World Bank Group (2021, p.95), the above-mentioned (a), (b), (c) and (d) 'create upward mobility in the sector, promote access, and allow any student to compete on a level playing field'. Hence, micro-learning, digital credentials, and the recognition of prior learning become of utmost importance in the era of 4IR.

2.5 Teaching and Learning Resources

Traditional learning in TVET mainly relied on classroom and workshop activities at TVET institutes, work-based learning during internships, and self-learning. Today, the adoption of technology-based solutions makes learning more interactive and helps to reduce the boundary between theory and practice (Blackburn-Dwyer, 2016). Further, learners get opportunities to practice at TVET institutes or industry partners using in digital technology facilitated training settings (Vinson, 2018). These changes demand that TVET move towards digitalization.

Although technology-based solutions are far ahead of traditional teaching resources and have the potential to enhance access to education and the quality and relevance of programme offerings, the acquisition and maintenance of technology-based solutions for teaching and learning demand higher infrastructure investment (Gonçalves, 2019; Veal and Dunbar, 2017). Further, the integration of digital technologies in teaching and learning requires updates and revisions to existing traditional didactical models (McGrath et al., 2020). Lack of resources for adapting curricula and training content was often identified as the reason for slow responses from TVET, which led to question about the labour market readiness of passed-out students. When financial support is taken into consideration, the cost of (or investments in) training delivery in digital ways is a function of the complexity and sophistication of training offerings. Hence, the digitalization of pedagogies calls for regular funding mechanisms for the digitalization process that includes the development, maintenance, and upgrade of systems (McGrath et al., 2020). At the institute and national levels, much reliance for funding is on private sector partners; many developing countries expect the support of donor agencies (Oketch, 2016). When infrastructure availability is taken into consideration, it involves ICT infrastructure and services, computing facilities and equipment, digital networks, and cloud storage services (Veal and Dunbar, 2017). However, one-time upgrades are not sufficient to keep pedagogies digitalized; rapid technological advances tend to be much faster compared to advances in education systems (McGrath et al., 2020). TVET institutes find it difficult to catch up with the latest pedagogical developments, which the industry expects their new recruits to be accustomed to, mainly due to financial and infrastructure challenges (Gonçalves, 2019). Hence, financial support and infrastructure availability are vital.

2.6 Staff Development, Support in The Profession, and New Staff Supply

Preparing staff for digital delivery is integral to TVET offerings and institutes' success. Staff development includes in-service preparation as well as continuous development in the profession. It is important to identify the importance of broad competencies in subject-specific, vocational pedagogical, digital, and transversal skills. For example, teaching staff should have capabilities in digital skills and competence in teaching subject content involving 4IR technologies used by the industry at the TVET institutes. Further, they should have digital skills to teach the subject content using 4IR technological tools. Therefore, teachers' digital skill requirements involve both capabilities to use digital technologies and capabilities to teach with digital technologies (Kukulska-Hulme and Traxler, 2020). These staff capacities are strong indicators of institutes' capacity and readiness to adapt to technological changes and respond to labour market needs (Wijewickrama & Wickramasinghe, 2022). Still, the digital skills of teachers continue to be the main limiting factor in TVET reaching its digitalization goals. In many

countries, digital competencies are not a mandatory component in teacher education, which makes teachers acquire these through continuous professional development (Mahdum et al., 2019; Whalley et al., 2021).

Further, without significant investments in the capacity development of staff, especially teaching staff, it is impossible to expect substantial payoffs in integrating 4IR digital technologies into programmes. The literature provides evidence for the implementation of staff incentive schemes to enhance their digital skills, institute-wide or nationwide digital skill programmes run by TVET regulatory bodies, and industry-TVET exchange programmes for teachers to develop work-based skills on 4IR technologies that are used in industry contexts (ILO, 2020). The support in the profession may include having professional freedom and pedagogical autonomy, access to sufficient teaching and learning materials, and direct and indirect support in the profession by TVET institutional leaders.

Furthermore, the SDG4 target 4.c recommends countries to increase the number of personnel, specifically, qualified teachers (The United Nations, n.d. a; UNESCO, n.d.). When new staff supply is taken into consideration, roles traditionally covered in designing, developing, and delivering programmes are now evolving into roles that require the contributions of several specialists such as programmers and media designers (ILO, 2020). Hence, new staff supply with the required credentials to use emerging 4IR technologies is vital for success.

2.7 Differences in TVET

The literature suggests that how well education institutes convert resources (inputs) into the teaching and learning process could vary (Busemeyer & Trampusch, 2012; Spöttl & Windelband, 2021). The present study seeks to examine differences in TVET in addressing the requirements of SDG4 and implementing 4IR competencies. For this purpose, two criteria were used, namely, institute type and regional classification of the country. We propose that differences in addressing the requirements of SDG4 and implementing 4IR competencies could be reflected in the relative importance given by respective institutes and geographic locations of the countries.

When institute type is considered, the education production could vary between different types of institutes. For example, Hanushek (2015) and Spöttl & Windelband (2021) showed possible differences between technical and vocational universities, polytechnics, and colleges. In this regard, the State shoulders the responsibility for the design, development, and maintenance of the TVET system with the participation of private donors. Still, the argument is that the status of education production at a particular TVET institute (e.g., colleges) could be different compared to other types of institutes (e.g., polytechnics) due to variations in the inputs used for education production as well as the characteristics of the labour market served by the institute (Persson & Hermelin, 2018). Having considered the importance of understating any differences in the education production by the institute type, it is proposed:

H1: Teaching and learning context, steps taken to impart skills for employment, and steps taken to enhance the capacities of staff differ by the institute type
H1a: Teaching and learning context differ by the institute type
H1b: Steps taken to impart skills for employment differ by the institute type
H1c: Steps taken to enhance the capacities of staff differ by the institute type

When the regional classification of the country is considered, education production could vary due to regional corporations between countries in specific regions (Oketch et al., 2009; Schröder, 2019). For example, skill migration interests of a region for continued economic and social development (Reeve, 2016). Such moves represent ideologies of political economy, which shape the quality of skilled personnel produced by the system. Therefore, how TVET serves the labour market could vary based on the region in which a country is located (Schröder, 2019). Furthermore, such regional differences may prevail irrespective of the introduction of global frameworks for the development of uniform TVET (ILO, 2020). This underscores the importance of understanding the regional differences and implications for policymaking. Hence, it is proposed:

H2: Teaching and learning context, steps taken to impart skills for employment, and steps taken to enhance the capacities of staff differ by the regional classification of the country
H2a: Teaching and learning context differ by the regional classification of the country
H2b: Steps taken to impart skills for employment differ by the regional classification of the country
H2c: Steps taken to enhance the capacities of staff differ by the regional classification of the country

3. Methodology

3.1 Sample

The countries included in the study are shown in Table 1. Of these countries, Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka are belonging to 'South Asia' while the remaining countries belonging to 'East Asia and Pacific'. Four hundred and twenty-eight TVET staff responded to the study from the countries shown in Table 1. Respondents were engaged in TVET at the tertiary level in STEM fields. We were provided the member directory of Colombo Plan Staff College located at the Philippines, who attended in-country programmes during the last three years from the countries selected for the study. The link to the online survey questionnaire was emailed to TVET staff who had undergone training programmes from the respective countries within the last three years. The respondents' profile is shown in Table 2.

Table 1 *Countries and characteristics*

Country	% out of total responses
Bangladesh	10.75
Bhutan	3.98
Cambodia	7
Fiji	1.17
India	14.95
Malaysia	5.37
Mongolia	1.64
Myanmar	6.07
Nepal	4.44
Pakistan	6.78
Papua New Guinea	1.64
Philippines	12.85
Sri Lanka	9.58
Thailand	6.78
Viet Nam	7

Notes: [1] = 428 (=100%)

Table 2 *Respondents' profile*

Characteristic	%	Characteristic	%
Region of the country:		Sex:	
South Asia	51.8	Female	24.9
East Asia & Pacific	48.2	Male	75.1
Institute type:		Age (in yrs):	
TVET teacher training/research institute	30.9	Mean	44.5
Polytechnic/TVET university	22.6	Std. Deviation	9.1
TVET college	46.5	Skewness	.06
Job type:		Highest education level:	
TVET administration	47.4	Doctorate	23.2
Academic staff	38.6	Master's degree	49.1
Academic support staff	2.1	Bachelor's degree	17.9
Technical staff	11.9	Certificate/diploma/higher diploma	9.8

3.2 Measures

The measures fall into three categories to match with objectives of the study and hypotheses proposed, which are shown in Table 3. We developed all the measures because of difficulties in finding prior studies that incorporated SDG4 and 4IR in TVET. The measures we developed for the study are given in Appendix 1.

Table 3 *Categories and sub-categories of measures*

Main Category	Sub-categories	Matching Hypotheses
Teaching and learning context	Curricula and training content	H1a and H2a
	Teaching and learning resources	
	Digital platforms used for teaching and learning	
Steps taken to impart skills for employment	Skills for 4IR incorporation	H1b and H2b
	Lifelong learning approach incorporation	
	Micro-credentials, digital credentials, and prior learning implementation	
Steps taken to enhance the capacities of staff	Training and development of TVET teachers	H1c and H2c
	Institutes' support in the profession and new staff hires	

The following well-established Likert scales were used in the questionnaire.
- 7-point Likert (strongly agree =7, agree = 6, More or less agree = 5, moderate = 4, More or less disagree = 3, disagree = 2, strongly disagree = 1),
- 5-point Likert scale (to a great extent = 5, much = 4, somewhat = 3, little = 2, not at all = 1),
- 3-point Likert scale (comprehensive and well-implemented formal system exists = 3, formal system exists but with some gaps in implementation = 2, no such system = 1).
- 3-point Likert scale for the extent of use of digital platforms (highly used = 3, the system exists but rarely used = 3, no such system/not used = 1).

3.3 Data Analysis Methods

First, the data were tested for any country-wise differences. Wilks' Lambda statistic suggested the non-existence of significant differences (p > 0.05) by country. Second, SPSS AMOS software was used for confirmatory factor analysis (CFA) for the 31-item scale. CFA yielded a normed chi-square statistic (χ^2/df) of 3.464, a comparative fit index (CFI) of .900, a Tucker-Lewis index (TLI) of .880, and a root mean square error of approximation (RMSEA) of .066 (for thresholds - Arbuckle, 2007). CFA estimates are shown in Table 4. Exploratory factor analysis (EFA) was conducted with SPSS for the types of digital platforms used. The results are shown in Table 5. Third, one-way ANOVA was used to test differences among the three institute types as well as two categories of regional classification (refer to Table 2). Mean values, standard error of the mean values (SE), and Partial eta squared (partial η^2) were calculated. The effect size was evaluated based on Partial eta squared.

Table 4 *CFA estimates - teaching and learning context, imparting skills for employment, and enhancing the capacities of staff*

Path			Estimate†
Incorporated 4IR competencies into the existing curriculum	←	Curricula and training content	.857***
Incorporated 4IR competencies into the existing modules	←	Curricula and training content	.858***
Additional modules added to existing programs incorporating 4IR competencies	←	Curricula and training content	.815***
Availability of support to design and revise curricula to address 4IR competencies	←	Curricula and training content	.762***
Adequate digital resources are available for online/digital delivery	←	Teaching and learning resources	.833***
Availability of financial support to purchase digital/technology-based resources to address 4IR competencies	←	Teaching and learning resources	.598***
Digital technology is used to deliver teaching and learning	←	Teaching and learning resources	.849***

Path			Estimate†
Introduced programs on digital skills to improve general digital literacy	←	Skills for 4IR incorporation	.837***
Introduced lifelong learning courses for reskilling and upskilling TVET diplomates/graduates on digital competencies	←	Skills for 4IR incorporation	.851***
Promote with academia, industry, and other stakeholders for mutual learning to address the needs of 4IR	←	Skills for 4IR incorporation	.875***
Availability of support mechanisms for industry collaboration for 4IR competency implementation	←	Skills for 4IR incorporation	.702***
Programmes offered go beyond secondary/post-secondary education to promote life-long learning of working adults	←	Lifelong learning approach incorporation	.795***
Programme delivery meets the needs of working adults or learners with family care responsibilities	←	Lifelong learning approach incorporation	.827***
TVET in my country established a social dialogue to popularize learning pathways	←	Lifelong learning approach incorporation	.765***
Youth and adults of my country see TVET as an alternative pathway to higher education	←	Lifelong learning approach incorporation	.762***
Programmes are offered with the use of digital technologies to increase the number of student enrolments	←	Lifelong learning approach incorporation	.798***
Programmes are offered for working adults	←	Lifelong learning approach incorporation	.801***
Specialized programmes of shorter duration are offered for working adults to advance their competencies	←	Micro-credentials, digital credentials, and prior learning implementation	.722***
Programmes offered can be stacked together to fulfil the requirements of a degree	←	Micro-credentials, digital credentials, and prior learning implementation	.749***
Digital credentials that are verified and signalled electronically are offered to those who successfully complete the programmes (which are different from a diploma/degree that is verified on paper-based examinations)	←	Micro-credentials, digital credentials, and prior learning implementation	.794***
Prior learning experience is recognized when enrolling for programmes/courses (digital micro-credentials)	←	Micro-credentials, digital credentials, and prior learning implementation	.747***
Higher education institutes (HEIs) in my country allow TVET learners to transfer credentials across HEIs when enrolling for programmes	←	Micro-credentials, digital credentials, and prior learning implementation	.798***
HEIs in my country recognize previous learning when enrolling for programmes	←	Micro-credentials, digital credentials, and prior learning implementation	.798***
Facilitate staff to update their knowledge on subject content to incorporate 4IR requirements	←	Training and development of TVET teachers	.891***
Facilitate staff to learn new pedagogies in line with 4IR requirements	←	Training and development of TVET teachers	.842***
Facilitate staff to learn new technological capabilities in line with 4IR requirements	←	Training and development of TVET teachers	.846***
Digital/technology-based teaching delivery is encouraged	←	Institutes' support in the profession and new staff hires	.832***

Path			Estimate†
Provide guidance and support to address the needs of 4IR	←	Institutes' support in the profession and new staff hires	.895***
Provide opportunities for staff to share their experiences on 4IR competency and technologies	←	Institutes' support in the profession and new staff hires	.873***
Availability of support to adopt online/digital teaching delivery mechanisms to address 4IR competencies	←	Institutes' support in the profession and new staff hires	.739***
Hire new staff with capabilities in 4IR competencies and technologies	←	Institutes' support in the profession and new staff hires	.885***

Note: † Standardised regression estimate, ***$p < 0.001$

Table 5 *EFA estimates - types of digital platforms*

Item	Estimate
LMS	.837
Video conferencing	.796
Social media	.771
MOOCs	.722
Open online educational resources	.714
Cronbach's alpha	.798
Eigenvalue	2.831
Explained variation	56.62

4. Findings

Findings are presented under three headings, namely, teaching and learning resources, steps taken to impart skills for employment, and steps taken to enhance the capacities of staff (Tables 6 to 13). Table 14 summarises the results of the hypotheses testing.

4.1 Teaching and Learning Resources

Table 6 shows results relating to curricula and training content with the values of mean, SE (in brackets) and Partial eta squared. The differences are significant for all areas by institute type ($p < .05$). Partial η^2 values of .059, .109, .078, and .044 suggest that institute type accounts for 6%, 11%, 8%, and 4% of the variance, respectively. These results support H1a. However, differences are not significant by region. Hence, H2a is not supported.

Table 6 *Curricula and training content*

	Total	Teacher training/ Research institute	Polytechnic/ TVET university	TVET college	F	Sig.	Partial η^2	South Asia	East Asia & Pacific	F	Sig.	Partial η^2
Incorporated 4IR competencies into the existing curriculum#	4.97 (.10)	5.43 (.18)	4.92 (.20)	4.55 (.16)	7.53	.001	.059	4.99 (.14)	4.92 (.14)	.16	.687	.001
Incorporated 4IR competencies into the existing modules#	4.99 (.10)	5.51 (.16)	5.02 (.19)	4.49 (.15)	14.75	.000	.109	5.02 (.14)	4.98 (.13)	.54	.464	.002
Additional modules added to existing programs incorporating 4IR competencies#	4.90 (.13)	5.49 (.17)	4.77 (.22)	4.42 (.16)	10.17	.000	.078	4.86 (.15)	4.94 (.13)	.77	.382	.003
Availability of support to design and revise curricula to address 4IR competencies##	2.05 (.05)	2.20 (.07)	1.93 (.09)	1.92 (.06)	5.56	.004	.044	2.02 (.06)	2.07 (.05)	.41	.523	.001

	Total	Teacher training/ Research institute	Polytechnic/ TVET university	TVET college	F	Sig.	Partial η^2	South Asia	East Asia & Pacific	F	Sig.	Partial η^2
Average	4.95 (.11)	5.48 (.17)	4.90 (.20)	4.49 (.16)	10.42	.000	.095	4.90 (.14)	4.49 (.13)	.05	.816	.000

Notes: # 7-point scale; ## 3-point scale, not included in average.

Table 7 shows results relating to teaching and learning resources. The results for all areas investigated support (p < .05) H1a, while they do not support H2a.

Table 7 *Teaching and learning resources*

	Total	Teacher training/ Research institute	Polytechnic/ TVET university	TVET college	F	Sig.	Partial η^2	South Asia	East Asia & Pacific	F	Sig.	Partial η^2
Digital technology is used to deliver teaching and learning #	5.56 (0.09)	6.00 (0.14)	5.62 (0.14)	5.09 (0.13)	13.44	.000	.101	5.46 (.16)	5.61 (.12)	.46	.497	.002
Adequate digital resources are available for online/digital delivery#	5.30 (0.10)	5.92 (0.15)	5.16 (0.21)	4.81 (0.15)	12.02	.000	.091	5.05 (.14)	5.58 (.12)	.18	.672	.001
Availability of financial support to purchase digital/technology-based resources to address 4IR competencies##	2.10 (.03)	2.29 (.06)	2.03 (.09)	1.99 (.05)	3.35	.037	.027	2.07 (.06)	2.09 (.06)	.13	.715	.000
Average	5.43 (.09)	6.07 (.16)	5.48 (.17)	4.95 (.15)	13.62	.000	.121	5.43 (.11)	5.30 (.16)	.33	.567	.001

Notes: # 7-point scale; ## 3-point scale, not included in average.

Table 8 shows the types of digital platforms used for teaching and learning. The differences were not significant for social media use by institute type (p > .05). This partially supports H1a. However, differences were significant only for the use of social media platforms by regional classification (p < .01). This partially supports H2a.

Table 8 *Types of digital platforms*

	Total	Teacher training/ Research institute	Polytechnic/ TVET university	TVET college	F	Sig.	Partial η^2	South Asia	East Asia & Pacific	F	Sig.	Partial η^2
Social media	2.52 (.04)	2.56 (.07)	2.5 (.08)	2.49 (.07)	2.92	.056	.024	2.71 (.05)	2.37 (.07)	8.17	.005	.029
Video conferencing	2.68 (.04)	2.75 (.05)	2.73 (.07)	2.56 (.05)	3.57	.030	.029	2.65 (.04)	2.67 (.05)	.00	.983	.000
Open online educational resources	1.86 (.06)	2.15 (.09)	1.75 (.10)	1.7 (.07)	11.57	.000	.088	1.86 (.06)	1.82 (.07)	.05	.827	.000
MOOCs	1.84 (.06)	2.17 (.09)	1.67 (.08)	1.56 (.07)	9.83	.000	.076	1.88 (.07)	1.76 (.07)	1.67	.194	.006
LMS	2.43 (.05)	2.57 (.07)	2.38 (.10)	2.31 (.07)	5.86	.003	.047	2.48 (.05)	2.35 (.07)	.06	.815	.000
Average	2.27 (.03)	2.50 (.06)	2.24 (.07)	2.14 (.05)	10.05	.000	.092	2.22 (.04)	2.39 (.06)	5.51	.020	.024

Notes: all on 3-point scale.

4.2 Steps Taken to Impart Skills for Employment

Table 9 shows the preparation of learners to equip them with skills for employment. The differences are significant for all areas by institute type ($p < .01$), supporting H1b. However, differences are not significant by regional classification ($p > .05$); H2b is not supported.

Table 9 *Skills for 4IR incorporation*

	Total	Teacher training/ Research institute	Polytechnic/ TVET university	TVET college	F	Sig.	Partial η^2	South Asia	East Asia & Pacific	F	Sig.	Partial η^2
Introduced programs on digital skills to improve general digital literacy[#]	5.35 (.09)	5.87 (.14)	5.24 (.18)	4.95 (.14)	9.88	.000	.076	5.34 (.13)	5.38 (.12)	1.07	.302	.004
Introduced lifelong learning courses for reskilling and upskilling TVET diplomates/graduates on digital competencies [#]	5.15 (.12)	5.77 (.15)	5.09 (.23)	4.59 (.16)	12.12	.000	.092	5.04 (.15)	5.29 (.13)	1.54	.216	.006
Promote close partnerships with stakeholders for mutual learning to address the needs of 4IR[#]	5.15 (.11)	5.69 (.17)	5.00 (.22)	4.87 (.16)	6.30	.002	.050	5.07 (.14)	5.27 (.12)	.54	.462	.002
Availability of support mechanisms for industry collaboration for 4IR competency implementation[##]	2.00 (.04)	2.17 (.07)	1.93 (.08)	1.90 (.06)	4.89	.008	.039	2.02 (.05)	1.98 (.06)	.30	.585	.001
Average	4.41 (.09)	4.88 (.13)	4.32 (.18)	4.08 (.13)	9.59	.000	.088	4.37 (.12)	4.48 (.11)	1.18	.277	.005

Notes: [#] 7-point scale; [##] 3-point scale, not included in average.

Table 10 shows results relating to the lifelong learning approach. The differences are significant for all areas by the institute type ($p > .05$). Therefore, H1b is not supported. However, the differences for all areas are significant by regional classification ($p < .01$), supporting H2b.

Table 10 *Lifelong learning approach incorporation*

	Total	Teacher training/ Research institute	Polytechnic/ TVET university	TVET college	F	Sig.	Partial η²	South Asia	East Asia & Pacific	F	Sig.	Partial η²
Programmes offered go beyond secondary/post-secondary education to promote life-long learning of working adults	4.17 (.04)	4.10 (.09)	4.29 (.09)	4.16 (.06)	1.39	.251	.006	4.02 (.07)	4.31 (.04)	15.34	.000	.027
Programme delivery meets the needs of working adults or learners with family care responsibilities	3.88 (.05)	3.91 (.09)	3.83 (.11)	3.90 (.07)	.24	.789	.001	3.69 (.07)	4.04 (.06)	14.01	.000	.024
TVET in my country established a social dialogue to popularize learning pathways	3.94 (.04)	3.99 (.09)	3.85 (.09)	3.96 (.06)	.69	.500	.003	3.79 (.07)	4.06 (.05)	11.09	.001	.019
Youth and adults of my country see TVET as an alternative pathway to higher education	3.91 (.05)	3.93 (.09)	3.85 (.10)	3.94 (.06)	.31	.735	.001	3.60 (.07)	4.22 (.05)	40.65	.000	.067
Programmes are offered with the use of digital technologies to increase the number of student enrolments	4.00 (.04)	3.99 (.08)	3.99 (.10)	4.01 (.06)	.02	.982	.000	3.88 (.07)	4.10 (.05)	7.15	.008	.013
Programmes are offered for working adults	3.99 (.05)	4.09 (.08)	3.89 (.11)	3.99 (.07)	1.16	.314	.005	3.80 (.07)	4.16 (.05)	13.77	.000	.024
Average	3.98 (.05)	4.00 (.09)	3.95 (.10)	3.99 (.06)	.01	.994	.000	3.80 (.07)	4.15 (.05)	.01	.007	.032

Notes: all on 5-point scale.

Table 11 shows results for the implementation of micro-credentials, digital credentials, and recognition of prior learning. The differences are not significant for all areas by institute type (p > .05). Hence, H1b is not supported. The differences are significant for all areas by regional classification (p < .05), supporting H2b.

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Table 11 *Micro-credentials, digital credentials, and prior learning implementation*

	Total	Teacher training/ Research institute	Polytechnic/ TVET university	TVET college	F	Sig.	Partial η^2	South Asia	East Asia & Pacific	F	Sig.	Partial η^2
Specialized programmes of shorter duration are offered for working adults to advance their competencies	4.05 (.05)	4.15 (.09)	3.91 (.10)	4.06 (.06)	1.89	.152	.008	3.93 (.06)	4.14 (.05)	6.50	.011	.011
Programmes offered can be stacked together to fulfil the requirements of a degree	3.80 (.05)	3.72 (.10)	3.84 (.09)	3.82 (.07)	.46	.633	.002	3.59 (.07)	3.98 (.05)	20.07	.000	.034
Digital credentials that are verified and signalled electronically are offered to those who successfully complete the programmes	3.65 (.06)	3.81 (.10)	3.57 (.11)	3.61 (.08)	1.54	.216	.006	3.44 (.08)	3.85 (.06)	19.42	.000	.033
Prior learning experience is recognized when enrolling for programmes/courses	3.95 (.05)	3.98 (.09)	3.97 (.09)	3.92 (.07)	.17	.841	.001	3.73 (.07)	4.15 (.05)	22.27	.000	.038
HEIs in my country allow TVET learners to transfer credentials across HEIs when enrolling for programmes	3.69 (.05)	3.66 (.10)	3.76 (.11)	3.68 (.07)	.28	.756	.001	3.44 (.08)	3.88 (.06)	24.02	.000	.041
HEIs in my country recognize previous learning when enrolling for programmes	3.82 (.05)	3.84 (.09)	3.81 (.10)	3.81 (.07)	.03	.975	.000	3.64 (.08)	3.98 (.05)	24.15	.000	.041
Average	3.83 (.05)	3.86 (.10)	3.81 (.10)	3.82 (.07)	.34	.713	.003	3.63 (.07)	4.00 (.05)	.18	.008	.061

Notes: all on 5-point scale.

4.3 Steps Taken to Enhance The Capacities of Staff

Table 12 shows findings related to the training and development of teachers. The differences are significant for all areas by institute type ($p < .001$), supporting H1c. However, the results do not support H2c ($p > .05$).

Table 12 *Training and development of TVET teachers*

	Total	Teacher training/ Research institute	Polytechnic/ TVET university	TVET college	F	Sig.	Partial η^2	South Asia	East Asia & Pacific	F	Sig.	Partial η^2
Facilitate staff to update their knowledge on subject content to incorporate 4IR requirements	5.16 (.12)	5.94 (.16)	4.85 (.20)	4.66 (.16)	13.33	.000	.100	5.01 (.14)	5.31 (.13)	.58	.447	.002
Facilitate staff to learn new pedagogies in line with 4IR requirements	5.22 (.10)	5.85 (.15)	4.96 (.21)	4.82 (.16)	10.81	.000	.083	5.15 (.14)	5.29 (.13)	.04	.837	.000
Facilitate staff to learn new technological capabilities in line with 4IR requirements	5.13 (.10)	5.55 (.17)	5.09 (.19)	4.7 (.15)	9.94	.000	.076	5.13 (.14)	5.12 (.13)	.00	.959	.000
Average	5.17 (.11)	5.78 (.16)	4.97 (.20)	4.73 (.16)	10.58	.000	.097	5.10 (.14)	5.24 (.13)	.77	.379	.003

Notes: all items on 7-point scale.

Table 13 shows institutes' support in the profession and new staff hires. The differences are significant for all areas by institute type ($p < .01$), supporting H1c. Since differences are not significant for all areas H2c is not supported ($p > .05$).

Table 13 *Institutes' support in the profession and new staff hires*

	Total	Teacher training/ Research institute	Polytechnic/ TVET university	TVET college	F	Sig.	Partial η²	South Asia	East Asia & Pacific	F	Sig.	Partial η²
Digital/technology-based teaching delivery is encouraged#	5.66 (.09)	5.96 (.16)	5.65 (.17)	5.35 (.13)	4.77	.009	.038	5.60 (.12)	5.71 (.10)	.02	.881	.000
Provide guidance and support to address the needs of 4IR#	5.17 (.09)	5.73 (.15)	5.05 (.18)	4.74 (.15)	12.67	.000	.095	5.18 (.13)	5.16 (.12)	.02	.903	.000
Provide opportunities for staff to share their experiences on 4IR competency and technologies#	5.13 (.11)	5.79 (.15)	4.8 (.19)	4.77 (.15)	9.57	.000	.074	5.07 (.13)	5.16 (.12)	.17	.678	.001
Hire new staff with capabilities in 4IR competencies and technologies#	4.90 (.12)	5.55 (.16)	4.71 (.22)	4.47 (.15)	11.26	.000	.086	4.86 (.14)	4.92 (.13)	.04	.850	.000
Availability of support to adopt online/digital teaching delivery mechanisms to address 4IR competencies##	2.12 (.04)	2.32 (.07)	2.11 (.08)	1.98 (.05)	6.64	.002	.052	2.15 (.05)	2.09 (.05)	.66	.416	.002
Average	5.23 (.10)	5.83 (.16)	5.09 (.18)	4.88 (.15)	9.30	.000	.086	5.18 (.12)	5.36 (.14)	.78	.377	.003

Notes: # 7-point scale; ## 3-point scale, not included in average.

The present study investigated the teaching and learning context, steps taken to impart skills for employment, and steps taken to enhance the capacities of staff. Accordingly, hypotheses were proposed as shown in Table 3. The findings shown in Tables 6 to 13 are used to test these hypotheses. Table 14 shows the results of the hypotheses testing.

Table 14 *Results of hypotheses testing*

Hypothesis	Areas investigated	Results	Differences by institute type	Differences by region
H1a and H2a - Teaching and learning context	Curricula and training content	Table 6	Supported	Not supported
	Teaching and learning resources	Table 7	Supported	Not supported
	Digital platforms used for teaching and learning	Table 8	Partially supported	Partially supported
H1b and H2b - Steps taken to impart skills for employment	Skills for 4IR incorporation	Table 9	Supported	Not supported
	Lifelong learning approach incorporation	Table 10	Not supported	Supported
	Micro-credentials, digital credentials, and prior learning implementation	Table 11	Not supported	Supported
H1c and H2c - Steps taken to enhance the capacities of staff	Training and development of TVET teachers	Table 12	Supported	Not supported
	Institutes' support in the profession and new staff hires	Table 13	Supported	Not supported

As shown in Table 14, the three hypotheses on 'curricula and training content', 'teaching and learning resources', skills for 4IR incorporation', and 'steps taken to enhance the capacities of staff' showed significant differences by institute type. However, we have not found significant differences in 'lifelong learning approach incorporation' and 'micro-credentials, digital credentials, and prior learning implementation' by the institute type. The two hypotheses on 'lifelong learning approach incorporation' and 'micro-credentials, digital credentials, and prior learning implementation' showed significant differences by the regional classification of the country. However, we have not found significant differences in 'curricula and training content', 'teaching and learning resources', skills for 4IR incorporation', and 'steps taken to enhance the capacities of staff' by the regional classification of the country. The hypothesis on the use of digital platforms for teaching and learning is partially supported as detailed in Table 8. The discussion of the findings, the contribution of the findings to the literature, and the implications of the findings for practice and policymaking are given in the next section.

5. Discussion of Findings and Contributions to Theory, Practice, and Policymaking

The world became aware of the terms 4IR and SDGs within almost the same timeline during the mid-2000s. If the year 2016 is accepted as the year that received prominence to 4IR (Schwab, 2016), the year 2015 is the year that the world accepted SDGs as a universal sustainable development agenda (The United Nations, n.d.). Today, the TVET systems across the world aim to adopt a more or less common framework, which allows youth and adults not only to find jobs in a particular country (local context) but also to move across countries for employment and migration. Therefore, it has become vital for TVET systems of different countries to respond to global trends with modern approaches. The findings of the study support the idea that the technological development of 4IR and SDGs correspond so well. Hence, when achieving one, the other cannot be ignored. SDG4, specifically targets 4.3, 4.4, and 4.c, has a strong relevance to TVET. We investigated teaching and learning context, steps taken to impart skills for employment, and steps taken to enhance the capacities of staff in relation to SDG4 and 4IR. When considering the influence of all these together, the findings support a fundamental shift along with SDG4 and 4IR, and the findings closely relate to the arguments of Gonçalves (2019), Reeve (2016), and Whalley et al. (2021). Still, the available literature incorporating SDG4, 4IR, and TVET is very limited in the mainstream literature. The literature available does not provide sufficient information for informed decision-making. Therefore, our study is novel and provides important information.

The literature on education production has addressed a wide array of topics (refer to Brewer et al., 2010; Busemeyer & Trampusch, 2012; Ling, 2015; Rossmiller & Geske, 1977). Still, much of the literature does not cover education production in the era of 4IR. The findings of our study support the arguments of Hanushek (2015) for the importance of attending to the efficiency of production. In this regard, efficiency is the relationship of inputs and outputs (Brewer et al., 2010). We developed survey item measures to investigate the inputs of TVET covering three main areas, namely, teaching and learning context, steps taken to impart skills for employment, and steps taken to enhance the capacities of staff in relation to SDG4 and 4IR. As argued by Hanushek (2015), education institutes rarely pay attention to efficiency in education production. When looking for efficiency, output measures or the quality and quantity of passed-out trainees should also be taken into consideration. However, how many trainees passed out and their achievements alone may not give a complete picture, as suggested in the literature (Brewer et al., 2010; Hanushek, 2015; Rossmiller & Geske, 1977).

The findings showed that video-conferencing platforms stand out as the most used platform across all countries, irrespective of the institute type or the regional classification of the country. As suggested by Blackburn-Dwyer (2016), the use of social media platforms remains useful for persistent learning, where students can stay in close contact with each other. Further, the findings support ILO (2020) that more reliance is on low-level digital technologies, which hold the highest potential for digitalization in the short run. The adoption of digital technology for teaching delivery can be viewed as an implementation of innovation. Then, the diffusion of innovation becomes important. A society's acceptance or rejection, as well as the level of adoption, are important to understand the diffusion of an innovation. For instance, the digitalization of pedagogies could be dependent on the extent of technological advancement expected to be experienced by the TVET system of a country and internal stakeholders' preparedness to adopt the digitalization of pedagogies. In this regard, the exposure of students during the COVID-19 to the use of digital technologies may lead to an increase in the maturity level of students towards heutagogy as well as an increase in the positive evaluations of TVET teachers of digital technologies and their willingness to incorporate heutagogical principles into their course designs. Further, conditions created during COVID-19 could have provided opportunities for the institutes to secure digital technologies for the teaching and learning process. All these could accelerate institutes' journey towards heutagogy, making heading for heutagogy not utopian. However, the cost of digitalization of pedagogies increases dramatically when a digital platform's complexity and sophistication increase. Since it is rare to find studies that compare digital technology use for pedagogies, the findings of the present study make another novel contribution to the literature.

Most importantly, the present study tested differences by institute type and regional classification of countries. The summary of results in Table 14 shows that the areas with significant differences by institute type are not significant by regional classification, and vice versa. Hence, two interesting patterns emerge. First, the differences are not significant by region for curricula and training content, teaching and learning resources, incorporation of skills for 4IR, training and development of TVET teachers, institutional support in the profession, and new staff hires. In other words, institutes produce personnel with globally or regionally relevant as well as acceptable or accredited qualifications. However, differences are significant by region for the incorporation of a lifelong approach in programme offerings and the implementation of micro-credentials, digital credentials, and prior learning recognition. The importance of flexibility in education offerings has received much attention during the last few years, such as Goger et al. (2022). Hence, our findings may imply that these areas are not very stringently adopted across regions. Hence, the findings support the argument (such as Schröder, 2019; Reeve, 2016) that regional differences exist in TVET offerings. Second, by institute type, TVET colleges showed the lowest performance, followed by polytechnic/TVET universities. The teacher training/research institutes topped in all areas, implying two things. First, these institutes are ranked at the highest level and represent the backbone of a country's TVET system, contributing to its growth. Hence, it could be expected that in years to come, the conditions of the other types of institutes will also be improved. These findings support the arguments of Persson and Hermelin (2018) and Spöttl and Windelband (2021).

5.1 Contribution to Existing Literature

The findings of the study showed the importance of incorporating emerging topics relating to education and training offerings, such as SDG4 and 4IR. The labour market and education system of economic sectors are drastically affected as a consequence of the developments of 4IR. SDG4 also takes a similar position in preparing for 4IR. The findings of the study emphasise the importance of rethinking the way education sectors operate. However, since the areas investigated in the present study are still emerging, it is rare to find in the academic literature with international and comparative standpoints. Hence, the findings presented in the study are valuable and novel.

The present study investigated the attempts to digitalize pedagogies. However, the literature on the digitalization of pedagogies in Asia and the Pacific is very limited. The focus on SDG4 and 4IR across institutes and geographic regions yielded fruitful outcomes. In this regard, the exposure of students during the COVID-19 to the use of digital technologies may lead to an increase in the maturity level of students towards digital technologies, as well as an increase in the positive evaluations of TVET teachers of digital technologies and their willingness to incorporate these into course designs. The findings support arguments such as Mahdum et al. (2019) and Kukulska-Hulme and Traxler (2020). Further, conditions created during COVID-19 could have provided opportunities for the institute to secure digital technologies for the teaching and learning process. Hence, the findings of the study contribute to the existing literature by providing evidence for the institutes' journey towards digitalization.

The adoption of digital technology for teaching delivery can be viewed as an implementation of innovation. Then, the diffusion of innovation becomes important. According to Rogers (2003), a society's acceptance or rejection, as well as the level of adoption, are important to understand the diffusion of an innovation. The findings of the study imply the level of technological advancement achieved by TVET institutes. Hence, the findings provide valuable insights into the achievements in digital technology for teaching delivery.

5.2 Contributions to Practice and Policymaking

The findings imply that the policymaking bodies must take active measures to increase the responsiveness of institutes in fulfilling SDG4 and addressing the challenges brought about by 4IR technologies for curricula and training content, skills for employment, teaching and learning resources, and teacher development in response. In this regard, the findings that showed colleges ranked as the weakest of all types of institutes are not a good sign. Most student enrolments occur at colleges compared to polytechnic/TVET universities. When TVET colleges have a lot of catching up to do, youth and adults enrolling for foundation programmes and continuing education programmes are at a disadvantage. Therefore, appropriate policies should be introduced and implemented across institutes, focusing on bridging the gap across different types of institutes.

Further, SDG4 gives prominence to lifelong learning. Along with this mandate, micro-credentials, digital credentials, and the recognition of prior learning assume greater importance. The differences in the status by regional classification suggest the need for appropriate policy directives to make these happen across geographic regions.

Furthermore, the preparation of students for the workplace as lifelong learners has two meanings. One is inclusivity, and the other is bridging the boundary between theory and practice. Digitalization of pedagogies not only impacts inclusivity but also impacts what, where, and how TVET students learn. First, delivery through digital means can reach a wider learner population, i.e., inclusivity or access to TVET education. Alternative

participation modes allow learners/intended learners to 'choose between participation modes in space and time' (Whalley et al., 2021, p.89). This may lead to higher enrolments for some groups of the population, who otherwise would not be included in higher education. Second, TVET provides skills in the domains of cognitive, technical, and socio-emotional. Digitalization can successfully integrate cognitive and technical components by reducing the boundary between theory and practice; learning can become more interactive and real-time. The use of learning activities on different digital platforms, providing diverse learning experiences and assessments, increases the quality of the learning experience. Our findings relate to both of these aspects, which ultimately lead to improved labour market outcomes. However, the findings of our study imply the need to assess the digitalization of pedagogies in different TVET institutes. The level of adoption and the availability of support mechanisms significantly vary by institute type. Considering the arguments made by Subasinghe and Wickramasinghe (2012) future studies should investigate whether differences prevail across TVET institutes in terms of cultural paradigms.

Overall, the findings underpin the necessity of assessing the future direction of TVET in the countries studied and policy directions to accelerate the production of trained individuals with appropriate and relevant skills.

6. Limitations and Future Research

Although it is recommended to implement SDG4 uniformly across countries, there can be country-specific priorities and timelines for achieving these. We have not incorporated such disparities in this study. We investigated key areas applicable to TVET in SDG4. However, SDG1 on poverty alleviation and SDG 8 on decent work are also some other SDGs to which TVET should contribute. This could be an interesting area for future studies. With regard to teaching and training content, SDG2 on agriculture productivity, SDG7 on clean energy, and SDG9 on sustainable industrialization and innovation are also areas where TVET can play a key role. Therefore, future studies could focus on these SDGs as well. Furthermore, today, the world is moving towards science, technology, engineering, arts, and mathematics (STEAM) to contribute more critical and entrepreneurial personnel to the labour market. Future research could expand to STEAM fields in TVET. Hence, the findings open several areas for future research.

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Conflict of Interest

There is no conflict of interest regarding the publication of the paper. The study does not involve funding, employment, financial, or non-financial related conflicts of interest to disclose.

Author Contribution

All authors contributed to the development of the paper from conception to draft and final review of the paper.

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Appendix 1. Item Measures in the Survey Questionnaire

Curricula and Training Content
Incorporated 4IR competencies into the existing curriculum
Incorporated 4IR competencies into the existing modules
Additional modules added to existing programs incorporating 4IR competencies
Availability of support to design and revise curricula to address 4IR competencies

Teaching and Learning Resources
Digital technology is used to deliver teaching and learning
Adequate digital resources are available for online/digital delivery
Availability of financial support to purchase digital/technology-based resources to address 4IR competencies

Skills for 4IR Incorporation
Introduced programs on digital skills to improve general digital literacy
Introduced lifelong learning courses for reskilling and upskilling TVET diplomates/graduates on digital competencies
Promote close partnerships with stakeholders for mutual learning to address the needs of 4IR
Availability of support mechanisms for industry collaboration for 4IR competency implementation

Lifelong Learning Approach Incorporation
Programmes offered go beyond secondary/post-secondary education to promote life-long learning of working adults
Programme delivery meets the needs of working adults or learners with family care responsibilities
TVET in my country established a social dialogue is present to popularize learning pathways
Youth and adults of my country see TVET as an alternative pathway to higher education
Programmes are offered with the use of digital technologies to increase the number of student enrolments
Programmes are offered for working adults

Micro-credentials, Digital Credentials, and Prior Learning Implementation
Specialized programmes of shorter duration are offered for working adults to advance their competencies
Programmes offered can be stacked together to fulfil the requirements of a degree
Digital credentials that are verified and signalled electronically are offered to those who successfully complete the programmes (which are different from a diploma/degree that is verified on paper-based examinations)
Prior learning experience is recognized when enrolling for programmes/courses (digital micro-credentials)
Higher education institutes (HEIs) in my country allow TVET learners to transfer credentials across HEIs when enrolling for programmes
HEIs in my country recognize previous learning when enrolling for programmes

Training and Development of TVET Teachers
Facilitate staff to update their knowledge on subject content to incorporate 4IR requirements
Facilitate staff to learn new pedagogies in line with 4IR requirements
Facilitate staff to learn new technological capabilities in line with 4IR requirements

Institutes' support in the profession and new staff hires
Digital/technology-based teaching delivery is encouraged
Provide guidance and support to address the needs of 4IR
Provide opportunities for staff to share their experiences on 4IR competency and technologies
Availability of support to adopt online/digital teaching delivery mechanisms to address 4IR competencies
Hire new staff with capabilities in 4IR competencies and technologies