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# Institutional implementation of Industry 4.0 competencies in TVET programmes in the Indo-Pacific: Critical success factors

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## ABSTRACT

This article responds to the question: What are the critical success factors that support the implementation of Industry 4.0 competencies in TVET (technical and vocational education and training) programme offerings? The scope of our study was programme offerings targeting STEM (science, technology, engineering and mathematics) fields at the tertiary level across 15 countries in the Indo-Pacific region. The study evaluated the 'actions already taken' to implement Industry 4.0 competencies, and a survey questionnaire was used to collect data. The findings identified staff capacity development, a supportive culture, the availability of resources, and public awareness as critical success factors. In addition, TVET institution type and the annual growth rate of real GDP (gross domestic product) per employed person were found to boost the relationship between these factors. This means that TVET colleges are in a weaker position in implementing Industry 4.0 compared with the other two types of institutions in the study.

## KEYWORDS

*Fourth Industrial Revolution (4IR); Indo-Pacific; Industry 4.0 competencies; technical and vocational education and training (TVET)*

## **Introduction**

Technical and vocational education and training (TVET) offers a combination of education, training and skills development opportunities in a wide range of occupational fields, production processes, services and livelihoods (ILO, 2020:21). The pedagogical approach of TVET is a mixture of theory, practice and work-based learning that leads to a qualification or other skills development options with a lifelong learning agenda at the secondary, post-secondary and tertiary levels. TVET institutions exercise the most influence and make the greatest contribution by incorporating qualifications and competencies into curricula, adopting appropriate teaching and learning practices, and building the capacity of staff – which are among the core functions of a TVET system (World Bank, 2021).

When TVET institutions set out to meet expectations, the incorporation of digital technologies tied to the Fourth Industrial Revolution (4IR) (commonly denoted as Industry 4.0) has become a necessity for two main reasons. First, to succeed in the volatile, uncertain, complex and ambiguous (VUCA) world that we currently live in (Millar, Groth & Mahon, 2018), TVET institutions must rely increasingly on Industry 4.0 technologies. This leads us to the second reason: Industry 4.0. Society has been undergoing dramatic transformations that are credited to Industry 4.0 digital technologies (World Economic Forum, 2016). In the context of work, Industry 4.0 technologies enable organisations to shift their operations as required by the VUCA world by creating smart workplaces. Shifting to Industry 4.0 technologies has become a part of national agendas; and the education sector as a whole should move forward with these agendas (World Bank, 2021).

Building on this context, we argue that the future of TVET is being shaped by Industry 4.0 technologies in two spheres. On the one hand, TVET should incorporate Industry 4.0 competencies into the curriculum of the existing and new programme offerings by defining learning objectives and mapping subject content onto learning outcomes. Here, TVET teachers possessing the subject content expertise in Industry 4.0 technologies and an understanding of the competencies to be incorporated into the curriculum are forming the core. On the other hand, Industry 4.0 technologies have been making a profound impact on the digitisation of pedagogies (Schröder, 2019; Spöttl & Windelband, 2021). Therefore, TVET should incorporate Industry 4.0 technologies into teaching, learning and assessment, and also into the development of teaching materials. In this respect, TVET teachers who possess the digital skills to use Industry 4.0 technologies and who also have the competencies to teach subject content using Industry 4.0 technologies form the core (World Bank, 2021).

The present study investigated 15 countries in the Indo-Pacific region. The literature from Indo-Pacific countries under study, on the one hand, suggests a lack of supply of skilled manpower (e.g. Bhattacharyya & Mitra, 2020; Butt et al., 2020) and questions the quality of the supply of skilled manpower delivered by TVET institutions (e.g. Jabarullah & Hussain, 2019). On the other hand, the literature highlights the challenges faced by TVET

institutions in areas such as financial and infrastructural (e.g. Gonçalves, 2019) matters, teacher capabilities (e.g. Mahdum, Hadriana & Safriyanti, 2019; Butt et al., 2020) and curriculum development (Butt et al., 2020). In addition, Gonçalves (2019) and Schröder (2019) suggest that the challenges faced by TVET institutions are common to Asia as a whole.

In the above context, we raise this question: What are the critical success factors that support the implementation of Industry 4.0 competencies in programme offerings? Accordingly, following the terminology introduced by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and used uniformly worldwide (2021:8) – specifically, *qualifications*, *competencies* and *implementation* – we investigated the factors that support the successful implementation of the competencies demanded by Industry 4.0 in programme offerings across 15 countries in the Indo-Pacific region. These are indicated in Table 1. The annual growth rate of real gross domestic product (GDP) per employed person is also identified because it is useful in understanding country ratings (Asian Development Bank, 2020:49).

**TABLE 1:** Countries and characteristics

COUNTRY	SAMPLE (% OF TOTAL RESPONSES) <sup>1</sup>	GDP GROWTH <sup>2</sup>
Bangladesh	10.75	5.9
Vietnam	7.00	5.8
Myanmar	6.07	5.4
Cambodia	7.00	5.3
Mongolia	1.64	5.3
India	14.95	4.8
Nepal	4.44	3.9
Bhutan	3.98	3.4
Philippines	12.85	3.3
Papua New Guinea	1.64	3.0
Thailand	6.78	2.7
Malaysia	5.37	2.6
Sri Lanka	9.58	2.5
Fiji	1.17	1.7
Pakistan	6.78	1.1

Notes: <sup>1</sup> = 428 (= 100%); <sup>2</sup> = Annual growth rate of real GDP per employed person.

## **Literature review**

### *Implementation of Industry 4.0 competencies in programme offerings*

The responses of TVET institutions to Industry 4.0 could inevitably move them towards digital transformation. Digital transformation involves digital adaptation, innovation and acceleration (ILO, 2020:25). With regard to digital adaptation, that is, ‘how Industry 4.0 technology requires teaching new content’ (ILO, 2020:25), the literature emphasises the need for Industry 4.0 technologies to become an integral part of TVET programme offerings (Schröder, 2019; Bhattacharyya & Mitra, 2020; Butt et al., 2020; Spöttl & Windelband, 2021). Industry expects, on the one hand, digital workflows currently in use to be reflected in programme offerings. On the other, with the continuing digitisation of work processes, industry requires workers to return to TVET institutions from time to time during their careers to remain relevant (ILO, 2020:60). This implies that TVET institutions must:

1. Update curricula and incorporate new content into their existing programmes;
2. Introduce new programmes to fulfil the requirements of new jobs, new occupations and new industry or to service sectors regularly and continuously; and
3. Introduce bridging programmes to reskill and upskill workers with lifelong learning in mind.

In doing so, forward-looking TVET systems must change their focus fourfold, that is, from:

- Academic pathways to applied learning pathways through internships for full-time courses;
- Classroom learning to work-based learning through work-study diploma pathways;
- Front-load learning to lifelong learning through accessible and bite-sized programmes for upgrading; and
- Technical skills to multidisciplinary skills through the integration of technical, transversal and citizenship skills.

With regard to digital innovation, that is, ‘how Industry 4.0 technology enables new forms of teaching and learning’ (ILO, 2020:25), Industry 4.0 technologies mediate knowledge in digital ways that enrich the teaching and learning process (ILO, 2020; TVET Academy, 2021). Industry 4.0 technologies can make a complete shift to the traditional teaching and learning practices of TVET. Today, students are expected either to learn theoretical aspects with the support of a variety of digital devices such as digitised textbooks, smart boards or tables and wearable gadgets, or to learn remotely through a digital platform, maintaining persistent learning by staying in near-constant contact with fellow students and teachers through mobile messaging apps (ILO, 2020). Students are expected to practise in a virtual, reality-based training environment provided by the TVET institution or its industry partners. This way of teaching and learning is a complete shift from learning theory

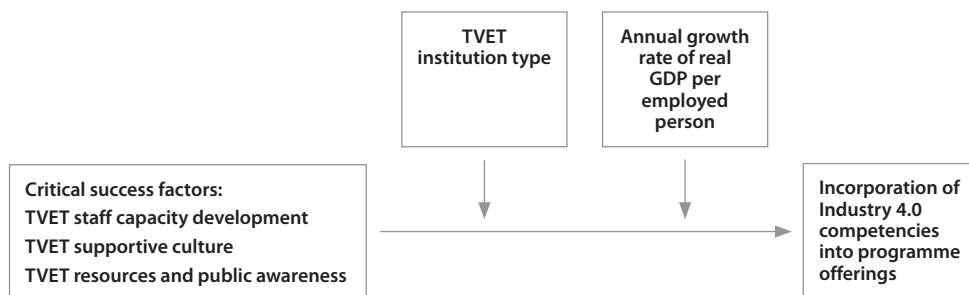
within the confines of a TVET institution's classroom, practising within the confines of its workshop, and refining and mastering capabilities by engaging in a real assignment on the site of an industry partner.

When both of these practical approaches are taken together – teaching new content and using new forms of teaching and learning – a student may learn the foundational content and skills through a TVET institution and then gain access to the labour market. They may continue to learn through opportunities provided by the employer or higher education institutions, depending on the requirements of the job and their career aspirations. These learning events may be integrated into their job as microlearning, and they may also engage in the learning using flexible learning avenues such as attending evening classes or using an online or distance mode. In line with this, therefore, Industry 4.0 technologies provide ample avenues for just-in-time learning.

In the present study, by 'implementation of Industry 4.0 competencies into programme offerings' we mean the extent to which institutions teach subject content by incorporating new content into existing programmes, introducing new programmes for newly emerged needs, introducing new programmes to reskill and upskill workers with lifelong learning in mind, and also the use of digital technology-based delivery modes in teaching and learning.

### *Critical success factors*

Given the importance of the successful implementation of Industry 4.0 competencies, it is imperative for institutions embarking on the implementation to have a greater understanding of the conditions that lead to success. Therefore, by the expression 'critical success factors' we mean the enabling conditions that are conducive to success in incorporating Industry 4.0 competencies into programme offerings. Building on the literature that is reviewed in the following sections, the conceptual model shown in Figure 1 has been developed for the present study.



**FIGURE 1:** Research model

## **TVET staff capacity development**

When putting the changes required by Industry 4.0 into practical effect, the key to success is TVET staff possessing the requisite capabilities. UNESCO (2021) has called on its member countries to develop mechanisms which ensure that TVET staff at all levels are given opportunities to prepare for the profession and engage in continuing training and professional development. With regard to areas of staff capacity development, three types of knowledge – content, pedagogical and technological – are vital. This means that staff competencies should be on a par with developments in Industry 4.0 technologies. However, the recent literature (e.g. Mahdum et al., 2019; Butt et al., 2020; ILO, 2020; Holler, Brändle & Zinn, 2023) suggests that TVET staff do not possess the requisite knowledge, especially technological knowledge, or the requisite level of digital competencies in particular. This has a direct impact on the potential of incorporating Industry 4.0 competencies into TVET programme offerings. Therefore, it is hypothesised that

H1: Staff capacity development enhances the incorporation of Industry 4.0 competencies into programme offerings.

## **TVET supportive culture**

The creation of a culture of innovation involving TVET staff at all levels (ILO, 2020), the promotion of exchanges between internal and external stakeholders (TVET Academy, 2021), the establishment of a multi-stakeholder collaboration system (ILO, 2020; TVET Academy, 2021; Amegah, 2023) and being open to change (ILO, 2020) were commonly identified as prerequisites for the survival and growth of TVET institutions. Furthermore, recent literature (e.g. Mahdum et al., 2019; Butt et al., 2020; World Bank, 2021) suggests the value of TVET institutions providing support for sharing experiences on Industry 4.0 competencies and technologies. In addition, the literature stresses the importance of TVET institutions providing support to effect changes to programme offerings (Alade & Windapo, 2020; World Bank, 2021). Therefore, it is hypothesised that

H2: A supportive culture enhances the incorporation of Industry 4.0 competencies into programme offerings.

## **TVET resources and public awareness**

The availability of resources such as equipment, computer hardware, software and a communication network for digital delivery, in addition to having the freedom to hire new staff with up-to-date competencies, are vital prerequisites. In this regard, the ILO (2020), the TVET Academy (2021) and the World Bank (2021) emphasise the importance of TVET institutions having the ability to identify appropriate technological infrastructure and also the autonomy to invest in such infrastructure. However, recent literature (e.g. Oketch, 2016; Gonçalves, 2019; ILO, 2020; McGrath et al., 2020; World Bank, 2021; TVET Academy, 2021) suggests that TVET institutions are experiencing financial and infrastructural shortages. Public awareness of Industry 4.0 technologies and changes to

programme offerings and academic pathways can also increase the demand for TVET programmes for beginner, intermediate or advanced learners and for bridging programmes with the intention of upskilling and reskilling the workforce. Therefore, it is hypothesised that

H3: The availability of resources and public awareness enhance the incorporation of Industry 4.0 competencies into programme offerings.

## **Contextual factors**

### *TVET institution type*

TVET institutions are at the front line of programme delivery (World Economic Forum, 2016; UNESCO, 2021). The literature also suggests the existence of different types of TVET institution, such as universities, polytechnics and colleges, that are involved in offering programmes in their entirety and/or their components (UNESCO-UNEVOC International Centre for TVET, 2020; World Bank, 2021). These TVET institutions are expected to offer quality, relevant and timely programmes that respond to labour market demands. However, recent literature (e.g. Persson & Hermelin, 2018; ILO, 2020; UNESCO, 2021) suggests that TVET institutions' capacity to respond may vary by institution type. For example, the ILO (2020:71) states:

[I]n most countries – even in advanced economies – basic pedagogies, such as those enabled by distance learning or by digitally enhanced classrooms, have not yet been mainstreamed across the entire educational system.

Recent studies, such as those by Yaakob (2017), Bai and Paryono (2019) and Marzuki et al. (2022) also provide evidence to suggest possible differences between TVET institutions in the Indo-Pacific region. Therefore, it is hypothesised that

H4: Institution type enhances the incorporation of Industry 4.0 competencies into programme offerings.

In line with Figure 1, the following hypotheses are also proposed:

H4a: Institution type moderates the relationship between staff capacity development and the extent of incorporation of Industry 4.0 competencies into programme offerings.

H4b: Institution type moderates the relationship between supportive culture and the extent of incorporation of Industry 4.0 competencies into programme offerings.

H4c: Institution type moderates the relationship between the availability of resources and public awareness and the extent of incorporation of Industry 4.0 competencies into programme offerings.

## **Annual growth rate of real GDP per employed person**

A country's TVET system and its capacity to provide skilled labour are central components of the political economy. The design and development of the system of TVET could vary from country to country due to the prevailing characteristics of the market economy and labour market relations. Furthermore, a country's status in technological upgrading or innovation, economic growth and employment growth go hand in hand. Sustainable Development Goal 8 (SDG 8) propounds the importance of promoting economic growth and labour productivity (UN, nd). One of the targets of SGD 8 is 'achieving higher levels of economic productivity through diversification, technological upgrading, and innovation, including through a focus on high-value added and labour-intensive sectors', which is depicted for each country by the indicator 'annual growth rate of real gross domestic product (GDP) per employed person' (identified as SDG8–8.2.1). This indicator conveys the idea of labour productivity.

The literature identifies an important connection between individuals participating in the labour market who have attained a tertiary education (vocational and university) and a country's annual growth rate of real GDP per employed person (Jongen, 2004; Marattin & Salotti, 2011). Bosler et al. (2019) referred to this as 'labour quality' and asserted this to be the value of educational attainment of those who participate in the labour market. Jongen (2004) referred specifically to the importance of adult education and training and suggested the existence of an important connection between returns from training and education efforts and a country's annual growth rate of real GDP per employed person. Therefore, it is hypothesised that

H5: The annual growth rate of real GDP per employed person enhances the incorporation of Industry 4.0 competencies into programme offerings.

In line with Figure 1, the following hypotheses are also proposed:

H5a: The annual growth rate of real GDP per employed person moderates the relationship between staff capacity development and the extent of incorporation of Industry 4.0 competencies into programme offerings.

H5b: The annual growth rate of real GDP per employed person moderates the relationship between supportive culture and the extent of incorporation of Industry 4.0 competencies into programme offerings.

H5c: The annual growth rate of real GDP per employed person moderates the relationship between the availability of resources and public awareness and the extent of incorporation of Industry 4.0 competencies into programme offerings.

Overall, the following hypotheses are proposed in line with Figure 1:

- H6: Institution type and the annual growth rate of real GDP per employed person moderate the relationship between staff capacity development and the extent of incorporation of Industry 4.0 competencies into programme offerings.
- H7: Institution type and the annual growth rate of real GDP per employed person moderate the relationship between a supportive culture and the extent of incorporation of Industry 4.0 competencies into programme offerings.
- H8: Institution type and the annual growth rate of real GDP per employed person moderate the relationship between the availability of resources and public awareness and the extent of incorporation of Industry 4.0 competencies into programme offerings.

## **Methodology**

We collected data from 15 countries in the Indo-Pacific region using a survey questionnaire. The details of the measures used, sample, method of data collection and methods of data analysis are presented in this section.

### *Measures*

As shown in Figure 1, the study had three independent variables, one dependent variable and two moderators. All the measures used in the study were developed by the authors. Furthermore, all the measures are based on a seven-point Likert scale ranging from strongly agree to strongly disagree (strongly agree = 7, agree = 6, more or less agree = 5, moderate = 4, more or less disagree = 3, disagree = 2, strongly disagree = 1). Furthermore, all the measures evaluated the 'actions already taken' instead of 'intend to do' or 'identified as important to do'. In addition, the scope was limited to the micro-level of programme implementation, that is, the TVET institutions, and used the terminology proposed by UNESCO (2021). The dependent variable was measured using the six-item scale shown in Table 3. The independent variables were measured by means of the 23-item scale shown in Table 4. The data point of the annual growth rate of real GDP per employed person applicable to each country was identified as per the Asian Development Bank (2020:49).

### *Sample and method of data collection*

We followed the definitions of the ILO (2020:60) and the UNESCO-UNEVOC International Centre for TVET (2020:7) for TVET staff. The sample comprised TVET staff at the tertiary level in the science, technology, engineering and mathematics (STEM) fields belonging to four broad categories – academic staff, academic support staff, technical staff and administration.

The Colombo Plan Staff College for Technician Education, located in the Philippines, allowed us access to its member directory of around 2 000 TVET staff from the countries selected for the study who had attended its in-country teacher training programmes during the past three years (see Table 1). We received 428 valid responses, as shown in Table 1, which represents a 21% response rate. The characteristics of the respondents are shown in Table 2.

**TABLE 2:** Characteristics of respondents

	%
GDP growth: <sup>1</sup>	
Less than 4% (low GDP growth)	52.88
4% or more (high GDP growth)	47.12
Institution type:	
TVET teacher training/research institute	30.9
Polytechnic/TVET university	22.6
TVET college	46.5
Job type:	
Administration	47.4
Academic staff	38.6
Academic support staff	2.1
Technical staff	11.9
Highest education level:	
Doctorate	23.2
Master's degree	49.1
Bachelor's degree	17.9
Certificate/diploma/higher diploma	9.8
Sex:	
Female	24.9
Male	75.1
Age (in years):	
Mean	44.47
Standard deviation	9.059
Minimum	25.00
Maximum	68.00
Skewness	0.064

*Notes:* <sup>1</sup> = refer to Table 1.

### *Methods of data analysis*

We tested the data for any differences by country using Wilks' Lambda statistic; the statistic showed the non-existence of significant differences ( $p > 0.05$ ), which was vital to proceeding with the data analysis. The data were tested for reliability, validity and factor structure, as shown in Tables 3 to 5.

**TABLE 3:** Incorporation of Industry 4.0 competencies into programme offerings

	FACTOR LOADING
My institution has incorporated Industry 4.0 competencies into the existing curriculum	0.894
My institution has incorporated Industry 4.0 competencies into the existing modules	0.897
My institution has introduced additional modules to incorporate Industry 4.0 competencies into the existing programmes	0.852
My institution has introduced programmes on digital skills to improve general digital literacy	0.896
My institution uses digital/technology-based delivery in teaching and learning	0.865
My institution has introduced lifelong learning courses to reskill and upskill TVET diplomates/graduates on Industry 4.0 competencies	0.871
Eigenvalue	4.716
Total variance explained	78.594
Cronbach's Alpha	0.904
Average variance extracted	0.773
Construct reliability	0.953

**TABLE 4:** Critical success factors

	F1: TVET STAFF CAPACITY DEVELOPMENT	F2: TVET SUPPORTIVE CULTURE	F3: TVET RESOURCES AND PUBLIC AWARENESS
My institution facilitates staff to update subject-content knowledge in line with Industry 4.0 requirements	0.894		
My institution facilitates staff to learn new pedagogies in line with Industry 4.0 requirements	0.843		
My institution facilitates staff to learn new technological capabilities in line with Industry 4.0 requirements	0.851		

	<b>F1: TVET STAFF CAPACITY DEVELOPMENT</b>	<b>F2: TVET SUPPORTIVE CULTURE</b>	<b>F3: TVET RESOURCES AND PUBLIC AWARENESS</b>
My institution has introduced programmes on digital skills to improve the general digital literacy of staff	0.908		
My institution recommends relevant training programs on Industry 4.0 competencies and technologies for staff	0.897		
My institution encourages the use of digital/technology-based delivery in teaching and learning		0.846	
My institution provides an understanding of competencies that should be developed for Industry 4.0		0.892	
My institution provides guidance and support to address the needs of Industry 4.0		0.896	
My institution provides opportunities for staff to share their experiences on Industry 4.0 competencies and technologies		0.843	
My institution promotes close partnerships with academia, industry, and other stakeholders for mutual learning to address the needs of Industry 4.0		0.894	
My institution encourages us to learn from past experience and deal effectively with Industry 4.0 challenges		0.833	
Overall, strategic goals of my institution are people-oriented, purpose-oriented and process-oriented towards Industry 4.0		0.889	
My institution hires new staff with capabilities in Industry 4.0 competencies and technologies			0.890
My institution has adequate resources (equipment, computer hardware, software and communication network) for on-line/digital delivery			0.853
My institution conducts awareness programmes for the industry on the importance of Industry 4.0 competencies and technologies			0.890
TVET regulating bodies in my country have consultants to advise on Industry 4.0 competency implementations			0.899

	F1: TVET STAFF CAPACITY DEVELOPMENT	F2: TVET SUPPORTIVE CULTURE	F3: TVET RESOURCES AND PUBLIC AWARENESS
My institution has consultants to advise on Industry 4.0 competency implementations			0.901
Eigenvalue	5.972	4.302	4.013
Total variance explained	32.678	28.437	21.821
Cronbach's Alpha	0.911	0.904	0.919
Average variance extracted	0.773	0.758	0.786
Construct reliability	0.944	0.956	0.948

**TABLE 5:** Correlations

		MEAN	SE	1	2	3	4	5	6
1	TVET institution type <sup>1</sup>	–	–	–					
2	GDP growth <sup>2</sup>	–	–	0.183**	–				
3	TVET staff capacity development	5.14	0.086	0.268**	0.118*	0.879			
4	TVET supportive culture	5.20	0.085	0.257**	0.090	0.521**	0.871		
5	TVET resources and public awareness	4.97	0.088	0.274**	0.140*	0.582**	0.514**	0.887	
6	Incorporation of Industry 4.0 competencies into programme offerings	5.08	0.084	0.327**	0.194*	0.668**	0.670**	0.529**	0.879

Notes: <sup>1</sup> = Nominal (multi-categorical – refer to Table 2); <sup>2</sup> = Nominal (binary coded – refer to Table 2); SE = Standard error of the mean; Diagonal entries are square root of average variance extracted; \* $p < 0.05$ , \*\* $p < 0.01$  (2-tailed).

The research model shown in Figure 1 was tested with a Hayes (2013) Process Macro for SPSS. We used 5 000 bootstrapped samples at bias-corrected 95% confidence intervals to test moderation effects. When coding moderators, the annual growth rate of real GDP per employed person (referred to as GDP growth) was binary coded (0 = less than 4% (low GDP growth) and 1 = 4% or more (high GDP growth) – refer to Table 2). Institution type was coded as a nominal variable having three categories (1 = TVET college, 2 = Polytechnic/TVET university and 3 = TVET teacher training or research institute).

## Findings and discussion

The results of the correlation analysis together with descriptive statistics are shown in Table 5. Table 6 indicates the results for the effect of staff capacity development on the dependent variable having both moderators.

**TABLE 6:** Effects of TVET staff capacity development on the incorporation of Industry 4.0 competencies into programme offerings

	R-sq	R2-chng	F	P
Overall effect on DV	0.7740	–	93.4676	0.0000
Highest-order unconditional interaction effects:				
IV1* Institution type	–	0.0073	3.0916	0.0577
IV1* GDP growth	–	0.0113	9.5341	0.0023
Effect of both moderators	–	0.0157	4.4116	0.0050

COEFFICIENTS:						
Variable	B	SE	T	p	LLCI	ULCI
IV1	0.9820	0.0711	14.1006	0.0000	0.8618	1.1421
W1	0.9628	0.4343	2.6774	0.0081	0.3062	2.0194
W2	0.9742	0.4843	2.5280	0.0123	0.2690	2.1794
Int_1	-0.1741	0.0844	-2.0640	0.0504	-0.3406	0.0077
Int_2	-0.1698	0.0857	-1.9816	0.0590	-0.3389	0.0008
GDP growth	0.9785	0.3885	3.0332	0.0028	0.4121	1.9448
Int_3	-0.2201	0.0713	-3.0877	0.0023	-0.3607	-0.0795

CONDITIONAL EFFECTS OF IV1 AT THE VALUES OF MODERATORS:							
Institution type	GDP growth	Effect	SE	t	P	LLCI	ULCI
1.0000	0.0000	1.0020	0.0711	14.1006	0.0000	0.8618	1.1421
1.0000	1.0000	0.7819	0.0502	15.5720	0.0000	0.6828	0.8809
2.0000	0.0000	0.8278	0.0852	9.7118	0.0000	0.6597	0.9959
2.0000	1.0000	0.6077	0.0738	8.2403	0.0000	0.4623	0.7532
3.0000	0.0000	0.8321	0.0694	11.9910	0.0000	0.6952	0.9690
3.0000	1.0000	0.6120	0.0809	7.5677	0.0000	0.4525	0.7716

BOOTSTRAP RESULTS FOR REGRESSION MODEL PARAMETERS:					
	B	BootMean	BootSE	BootLLCI	BootULCI
Int_3	-0.2201	-0.2189	0.0874	-0.3915	-0.0466

*Notes: DV = Incorporation of Industry 4.0 competencies into programme offerings; IV1 = Staff capacity development; Reference category of institution type = TVET college, W1 = Polytechnic/TVET university vs TVET college; W2 = TVET teacher training/research institute vs TVET college; Int\_1 = Product term of IV1 and W1; Int\_2 = Product term of IV1 and W2; Int\_3 = Product term of IV1 and GDP growth.*

Statistics for the overall model involving IV1, moderators (institution type and GDP growth), interactions and DV show that the overall model is significant ( $R\text{-sq} = 0.7740$ ,  $p < 0.001$ ). First, when considering the main effects, the effect of IV1 on DV is significant ( $t = 14.10$ ,  $p < 0.001$ ), where IV1 increases, DV also increases. This supports H1.

When considering the effect of institution type on DV, the difference in DV between Polytechnic/TVET universities and TVET colleges is significant ( $W1$ ,  $t = 2.68$ ,  $p < 0.01$ ): Polytechnic/TVET universities have implemented more in comparison with TVET colleges. Furthermore, the difference in DV between TVET teacher training/research institutes and TVET colleges is significant ( $W2$ ,  $t = 2.53$ ,  $p < 0.05$ ): TVET teacher training/research institutes have implemented more in comparison with TVET colleges.

When considering the effect of GDP growth on DV, the difference in DV between low-GDP-growth countries and high-GDP-growth countries is significant (GDP growth,  $t = 3.03$ ,  $p < 0.01$ ): high-GDP-growth countries have implemented more in comparison with low-GDP-growth countries.

Second, considering the interaction effects, both the interaction effects of institution type are not significant ( $Int\_1$ ,  $p > 0.05$ ;  $Int\_2$ ,  $p > 0.05$ ). In detail, although the impact of IV1 on DV in Polytechnic/TVET universities is considerably different (lower) from that of TVET colleges ( $Int\_1$ ,  $t = -2.06$ ,  $p > 0.05$ ) and the impact of IV1 on DV in TVET teacher training/research institutes is considerably different (lower) from that of TVET colleges ( $Int\_2$ ,  $t = -1.98$ ,  $p > 0.05$ ), these differences are not significant. These results do not support H4a.

However, the interaction effect of GDP growth is significant ( $Int\_3$ ,  $t = -3.09$ ,  $p < 0.01$ ).  $Int\_3$  negatively moderates the relationship between IV1 and DV, that is, the impact of IV1 on DV in high-GDP-growth countries is considerably different (lower) from that of low-GDP-growth countries. This supports H5a.

Third, the results of the test of unconditional interaction effects show that the change in R-sq due to the interaction of GDP growth (IV1\*GDP growth, i.e.  $Int\_3$ ,  $p < 0.05$ ) is significant. Although the change in R-sq due to the interaction of institution type (IV1\* Institution type,  $p > 0.05$ ) is not significant, overall, the change in R-sq due to both interactions is significant ( $p < 0.01$ ). The conditional effects (or simple slopes) for IV1 to DV at a given level of institution type and GDP growth show that, at all levels of institution type and GDP growth, IV1 significantly predicts DV. For example, IV1 predicting DV is significant at the institutional type 1 (i.e. TVET college) and GDP growth group 0 (i.e. low-GDP-growth countries). Likewise, IV1 predicting DV is significant at the institutional type 1 (i.e. TVET college) and GDP growth group 1 (i.e. high-GDP-growth countries), and so on.

Finally, the bootstrap confidence intervals (BootLLCI and BootULCI) for  $Int\_3$  do not include zero, where both have negative values. Therefore, the regression weight significantly

differs from zero, fulfilling the condition for moderation (refer to Hayes, 2013). This supports H6.

Table 7 shows the results for the effect of supportive culture on the dependent variables having both moderators.

**TABLE 7:** Effect of TVET supportive culture on the incorporation of Industry 4.0 competencies into programme offerings

	<b>R<sup>2</sup><sub>sq</sub></b>	<b>R2-chng</b>	<b>F</b>	<b>P</b>
Overall effect on DV	0.7981	–	131.5714	0.0000
Highest-order unconditional interaction effects:				
IV2*Institution type	–	0.0065	3.7658	0.0246
IV2*GDP growth	–	0.0022	2.5293	0.1131
Effect of both moderators	–	0.0076	2.9125	0.0352

<b>COEFFICIENTS:</b>						
Variables	<i>B</i>	SE	<i>T</i>	<i>p</i>	LLCI	ULCI
IV2	0.9385	0.0522	17.9952	0.0000	0.8357	1.0412
W1	0.8826	0.3972	2.2222	0.0272	0.1001	1.6651
W2	0.9849	0.3941	3.2856	0.0012	0.5184	2.0714
Int_1	–0.1310	0.0765	–1.7134	0.0880	–0.2817	0.0196
Int_2	–0.1805	0.0704	–2.5638	0.0110	–0.3191	–0.0418
GDP growth	0.4677	0.3108	1.5047	0.1338	–0.1447	1.0800
Int_3	–0.0924	0.0581	–1.5904	0.1131	–0.2068	0.0221

<b>CONDITIONAL EFFECTS OF IV2 AT VALUES OF MODERATORS:</b>							
Institution type	GDP growth	Effect	SE	<i>t</i>	<i>p</i>	LLCI	ULCI
1.0000	0.0000	0.9385	0.0522	17.9952	0.0000	0.8357	1.0412
1.0000	1.0000	0.8461	0.0472	17.9158	0.0000	0.7531	0.9392
2.0000	0.0000	0.8075	0.0724	11.1536	0.0000	0.6648	0.9501
2.0000	1.0000	0.7151	0.0701	10.1959	0.0000	0.5769	0.8533
3.0000	0.0000	0.7580	0.0583	12.9973	0.0000	0.6431	0.8730
3.0000	1.0000	0.6657	0.0688	9.6737	0.0000	0.5301	0.8013

BOOTSTRAP RESULTS FOR REGRESSION MODEL PARAMETERS:					
	B	BootMean	BootSE	BootLLCI	BootULCI
Int_2	-0.1805	-0.1819	0.0731	-0.3232	-0.0383

*Notes: DV = Incorporation of Industry 4.0 competencies into programme offerings; IV2 = Supportive culture; Reference category of institution type = TVET college, W1 = Polytechnic/TVET university vs TVET college; W2 = TVET teacher training/research institute vs TVET college; Int\_1 = Product term of IV2 and W1; Int\_2 = Product term of IV2 and W2; Int\_3 = Product term of IV2 and GDP growth.*

Stated succinctly, the overall model is significant. First, the effect of IV2 on DV is significant. This supports H2. The difference in DV between Polytechnic/TVET universities and TVET colleges is significant; the difference in DV between TVET teacher training/research institutes and TVET colleges is significant. The difference in DV between low-GDP-growth countries and high-GDP-growth-countries is not significant.

Second, considering the interaction effects, the impact of IV2 on DV in Polytechnic/TVET universities versus TVET colleges is not significant. However, the impact of IV2 on DV in TVET teacher-training/research institutes versus TVET colleges is significant. Overall, the results partly support H4b. The interaction effect of GDP growth is not significant, though, which result does not support H5b.

Third, the results of the test of unconditional interaction effects show that the change in R-sq due to the interaction of institution type is significant ( $p < 0.05$ ); the overall change in R-sq due to both interactions is significant ( $p < 0.05$ ). At all levels of institution type and GDP growth, IV2 significantly predicts DV. Finally, bootstrap confidence intervals show that the condition for moderation is satisfied. This supports H7.

Table 8 shows the results for the effect of availability of resources and public awareness on the dependent variable having both moderators.

**TABLE 8:** Effect of TVET resources and public awareness on the incorporation of Industry 4.0 competencies into programme offerings

	R-sq	R2-chng	F	P
Overall effect on DV	0.7286	-	73.2523	0.0000
Highest-order unconditional interaction effects:				
IV3*Institution type	-	0.0080	2.8037	0.0631
IV3*GDP growth	-	0.0041	2.9041	0.0900
Effect of both moderators	-	0.0103	2.4249	0.0670

COEFFICIENTS:						
Variables	B	SE	T	p	LLCI	ULCI
IV3	0.9171	0.0742	12.3648	0.0000	0.7708	1.0634
W1	0.9725	0.4521	3.0802	0.0024	0.5008	2.2842
W2	0.9585	0.5002	2.1160	0.0356	0.0718	2.0452
Int_1	-0.2083	0.0923	-2.2561	0.0252	-0.3905	-0.0262
Int_2	-0.1362	0.0908	-1.5002	0.1352	-0.3153	0.0429
GDP growth	0.7265	0.3949	1.8397	0.0674	-0.0524	1.5054
Int_3	-0.1274	0.0748	-1.7042	0.0900	-0.2749	0.0201

CONDITIONAL EFFECTS OF IV3 AT VALUES OF MODERATORS:							
Institution type	GDP growth	Effect	SE	t	P	LLCI	ULCI
1.0000	0.0000	0.9171	0.0742	12.3648	0.0000	0.7708	1.0634
1.0000	1.0000	0.7896	0.0577	13.6967	0.0000	0.6759	0.9034
2.0000	0.0000	0.7087	0.0852	8.3226	0.0000	0.5408	0.8767
2.0000	1.0000	0.5813	0.0827	7.0320	0.0000	0.4182	0.7444
3.0000	0.0000	0.7809	0.0746	10.4692	0.0000	0.6337	0.9280
3.0000	1.0000	0.6534	0.0843	7.7528	0.0000	0.4872	0.8197

BOOTSTRAP RESULTS FOR REGRESSION MODEL PARAMETERS:					
	B	BootMean	BootSE	BootLLCI	BootULCI
Int_1	-0.2083	-0.2121	0.1077	-0.4209	-0.0017

*Notes: DV = Incorporation of Industry 4.0 competencies into programme offerings; IV3 = Resources and public awareness; Reference category of institution type = TVET college, W1 = Polytechnic/TVET university vs TVET college; W2 = TVET teacher training/research institute vs TVET college; Int\_1 = Product term of IV3 and W1; Int\_2 = Product term of IV3 and W2; Int\_3 = Product term of IV3 and GDP growth.*

Stated succinctly, the overall model is significant. First, the effect of IV3 on DV is significant. This supports H3. The difference in DV between Polytechnic/TVET universities and TVET colleges is significant; the difference in DV between TVET teacher training/research institutes and TVET colleges is significant. The difference in DV between high-GDP-growth countries and low-GDP-growth countries is not significant.

Second, considering interaction effects, the impact of IV3 on DV in Polytechnic/TVET universities versus TVET colleges is significant. However, the impact of IV3 on DV in TVET teacher training/research institutes versus TVET colleges is not significant. Overall, the results partly support H4c. Furthermore, the interaction effect of GDP growth is not significant. This result does not support H5c. Third, the results of the test of unconditional interaction effects show that the change in R-sq due to the interaction of institution type

is significant ( $p < 0.10$ ); the overall change in R-sq due to both interactions is significant ( $p < 0.10$ ). At all levels of institution type and GDP growth, IV3 significantly predicts DV.

Finally, bootstrap confidence intervals show that the condition for moderation is satisfied. This supports H8.

In Table 9 the findings of the study are summarised, indicating, overall, those effects that supported which hypothesis and the corresponding table in which the data are presented.

**TABLE 9:** Summary of findings

EFFECT	HYPOTHESIS	RESULT	CORRESPONDING TABLE	DESCRIPTION
Staff capacity development → DV	H1	Supported	Table 6	Staff capacity development enhances DV ( $p < 0.001$ )
Supportive culture → DV	H2	Supported	Table 7	Supportive culture enhances DV ( $p < 0.001$ )
Resources and public awareness → DV	H3	Supported	Table 8	Resources and public awareness enhance DV ( $p < 0.001$ )
Institution type → DV	H4	Supported	Table 6	Institution type on DV is significant between Polytechnic/TVET universities and TVET colleges ( $p < 0.01$ ) and between TVET teacher training/research institutes and TVET colleges ( $p < 0.05$ )
			Table 7	Institution type on DV is significant between Polytechnic/TVET universities and TVET colleges ( $p < 0.05$ ) and between TVET teacher training/research institutes and TVET colleges ( $p < 0.01$ )

EFFECT	HYPOTHESIS	RESULT	CORRESPONDING TABLE	DESCRIPTION
			Table 8	Institution type on DV is significant between Polytechnic/TVET universities and TVET colleges ( $p < 0.05$ ) and between TVET teacher training/research institutes and TVET colleges ( $p < 0.05$ )
Staff capacity development → DV having institution type as a moderator	H4a	Not supported	Table 6	Interaction effects of institution type are not significant at all levels
Supportive culture → DV having institution type as a moderator	H4b	Partly supported	Table 7	Interaction effect in Polytechnic/TVET universities versus TVET colleges is not significant; TVET teacher training/research institutes versus TVET colleges is significant ( $p < 0.05$ )
Resources and public awareness → DV having institution type as a moderator	H4c	Partly supported	Table 8	Interaction effect in Polytechnic/TVET universities versus TVET colleges is significant ( $p < 0.05$ ); TVET teacher training/research institutes versus TVET colleges is not significant
GDP growth → DV	H5	Partly supported	Table 6	GDP growth is significant ( $p < 0.01$ ) between low-GDP-growth countries and high-GDP-growth countries
			Table 7	GDP growth is not significant ( $p > 0.05$ ) between low-GDP-growth countries and high-GDP-growth countries
			Table 8	GDP growth is not significant ( $p > 0.05$ ) between low-GDP-growth countries and high-GDP-growth countries

EFFECT	HYPOTHESIS	RESULT	CORRESPONDING TABLE	DESCRIPTION
Staff capacity development → DV having GDP growth as a moderator	H5a	Supported	Table 6	Interaction effects of GDP growth is significant ( $p < 0.01$ )
Supportive culture → DV having GDP growth as a moderator	H5b	Not supported	Table 7	Interaction effect of GDP growth is not significant
Resources and public awareness → DV having GDP growth as a moderator	H5c	Not supported	Table 8	Interaction effect of GDP growth is not significant
Model 1 – Staff capacity development on DV having both institution type and GDP growth as moderators	H6	Supported	Table 6	$\Delta R^2$ due to the interaction of GDP growth is significant ( $p < 0.05$ ); $\Delta R^2$ due to the interaction of institution type is not significant $\Delta R^2$ due to both interactions is significant ( $p < 0.01$ ) At all levels of institution type and GDP growth, staff capacity development significantly predicts DV ( $p < 0.001$ for all levels)
Model 2 – Supportive culture on DV having both institution type and GDP growth as moderators	H7	Supported	Table 7	$\Delta R^2$ due to the interaction of institution type is significant ( $p < 0.05$ ) $\Delta R^2$ due to the interaction of GDP growth is not significant $\Delta R^2$ due to both interactions is significant ( $p < 0.05$ ) At all levels of institution type and GDP growth, supportive culture significantly predicts DV ( $p < 0.001$ for all levels)

EFFECT	HYPOTHESIS	RESULT	CORRESPONDING TABLE	DESCRIPTION
Model 3 – Resources and public awareness on DV having both institution type and GDP growth as moderators	H8	Supported	Table 8	<p><math>\Delta R^2</math> due to the interaction of institution type is significant (<math>p &lt; 0.10</math>)</p> <p><math>\Delta R^2</math> due to the interaction of GDP growth is not significant</p> <p><math>\Delta R^2</math> due to both interactions is significant (<math>p &lt; 0.10</math>)</p> <p>At all levels of institution type and GDP growth, resources and public awareness significantly predict DV (<math>p &lt; 0.001</math> for all levels)</p>

### Implications of the findings

The study found that the three critical success factors – TVET staff capacity development, TVET supportive culture and the availability of resources and public awareness – significantly predict the implementation of Industry 4.0 competencies positively into programme offerings. It was also found that institution type and annual growth rate of real GDP per employed person boost the relationship between these factors. Of the three institution types, TVET colleges were in a weaker position compared with the other two (see Table 9). Regarding the annual growth rate of real GDP per employed person, countries with high growth rates have implemented more in comparison with countries with low growth rates. The findings have important implications for the literature, practice and policymaking across countries, regions and continents.

With regard to the theoretical contributions, first, while there is widespread agreement that Industry 4.0 technologies are having a profound impact on the agenda of education, the literature, such as Spöttl and Windelband (2021) and Schröder (2019), suggests that limited research attention has been paid so far to investigating the success factors behind the implementation of Industry 4.0 competencies in higher education programmes. Therefore, our research is an attempt to make a valuable contribution to the literature at the regional or even a global level.

Second, the World Bank (2021) and UNESCO (2021) have proposed the establishment of almost uniform TVET systems within and across countries. Still, there can be differences due to certain characteristics within countries. We investigated two such characteristics: TVET institution type and annual growth rate of real GDP per employed person. We found that institution type has a direct effect on the implementation of Industry 4.0 competencies (DV); and it is also an important moderator which can have a significant impact on the variables of

interest (IVs) (see Table 9). Regarding the annual growth rate of real GDP per employed person, when a country is behind in economic development and performs poorly in maintaining labour markets, there could be limited job openings for those with middle-level technical expertise, with accompanying attractive labour market rewards. This suggests the importance of assessing the impact of the annual growth rate of real GDP per employed person. We have not found any previous studies that have tried to integrate such country-context variables into cross-country investigations. Our proposition was that when a country's annual growth rate of real GDP per employed person is higher, that country could place a higher weight on its TVET system for lower- and middle-level job creation, in this way helping to relieve poverty and unemployment in the country. The findings of the present study provide evidence to suggest that the annual growth rate of real GDP per employed person affects the implementation of Industry 4.0 competencies (DV) and operates as an important moderator (see Table 9). We therefore believe that our incorporation of this indicator as a moderator would possibly provide novel insights and make valuable contributions to the literature.

Third, since the sample covered 15 countries, there is much potential to generalise the findings across countries – the importance of generalisability across countries having been constantly expressed in the literature on TVET (e.g. Schröder, 2019; World Bank, 2021). Our research provides empirical findings at a critical time in research on TVET with the dawning of Industry 4.0. Moreover, the critical success factors we have identified in the Indo-Pacific region could be extended beyond this region: researchers from other regions and continents could use the measures developed by us in future investigations for comparative purposes. Therefore, our research makes valuable contributions to research in this niche.

We are able to identify several implications for practice. First, the findings showed the importance of developing staff capacity. At the institutional level, promoting the acquisition of the requisite competencies (new subject content knowledge, technology use and pedagogies), offering assistance by providing self-learning options, and offering support in the form of recommending development programmes, are important. In addition, the responsibility for developing staff capacity cannot be regarded as the sole responsibility of the TVET institutions. Staff should also take responsibility for their own professional development and for staying relevant. They should be passionate, espouse self-determination and possess a sense of ownership if they are to succeed and build on their careers.

The second implication of our findings is that, as a part of supporting culture, TVET institutions must consider promoting staff-exchange programmes with industry to keep staff abreast of technological developments in work processes. Furthermore, the institutions should provide support through recommendations, encouragement, guidance and communities of practice in order to update staff competencies – including subject content knowledge, the use of digital platforms and tools, and pedagogical practice. The findings suggest the need for initiatives between academia, industry and other stakeholders for mutual learning to engage in constant dialogue to respond to the requirements of Industry 4.0 in order to promote curriculum development, staff capacity-building and student apprenticeship or internship training.

The third implication of the findings is that the autonomy and capacity of TVET institutions to hire new staff with Industry 4.0 competencies and technologies, to acquire appropriate digital infrastructure for developing a conducive teaching and learning environment, and to enter into agreements or partnerships with digital service providers such as broadband can lead to the successful implementation of Industry 4.0 competencies in programme offerings. In this regard, previous research highlighted the importance of financing TVET programmes (e.g. Oketch 2016; Gonçalves, 2019; McGrath et al., 2020; World Bank, 2021). In addition, the findings imply that TVET institutions must maintain a close connection with the public (mainly industrial sectors as a whole) to publicise the value of implementing Industry 4.0 technologies in workplaces.

The present study also has implications for policymaking. What, when and how to transform economies and societies along with Industry 4.0 should occupy a major portion of the national agenda of all countries. Our findings on the two moderators suggest some implications for policymaking. First, it is the ultimate responsibility of the state to take appropriate policy decisions to provide all types of TVET institutions with opportunities for inclusive growth. A state's policies and initiatives for creating a multi-stakeholder collaboration system for TVET, for example, may reduce disparities at the institutional level and may boost institutions' capacity to implement Industry 4.0 competencies in their programme offerings.

Second, the extent of preparedness of a country to take advantage of Industry 4.0 could be indicated by national-level economic indicators such as the annual growth rate of real GDP per employed person. TVET institutions are influenced by the nature of economic conditions. Our findings showed that the annual growth rate of real GDP per employed person could operate as a moderating factor and affect the implementation of Industry 4.0 competencies in programme offerings. This suggests that a country's policies and actions on employment generation, technological upgrading and innovation will bring about economic transformation and help to yield higher levels of productivity; with these transformations, changes to institutions' programme offerings are highly likely.

## **Conclusion**

Given the accelerating pace of the changes occurring as a result of Industry 4.0, the existence of research studies on the response of higher education in programme offerings is disproportionately small worldwide. In response to this backdrop, we questioned what the critical success factors are that support the implementation of Industry 4.0 competencies in TVET programme offerings. Our study identified some critical success factors that are associated with incorporating competencies into programme offerings, adopting appropriate teaching and learning practices, and building staff capacity in the context of Industry 4.0. The findings also pointed to the role of two moderators in boosting the implementation of Industry 4.0 competencies in programme offerings.

## Limitations and future research

First, our scope was limited to TVET institutions at the tertiary level in STEM fields. It is imperative that the conditions intermingled together influence successful implementations. Nevertheless, we believe that our findings should inspire future researchers to expand meaningfully the depth and breadth of future investigations. Regarding future research, the level of TVET system understudy can be broadened to include the macro- or meso-levels. Furthermore, the findings on moderators imply that a country's policies could enhance the types of programme offered and the way in which these are delivered. Furthermore, the present study was limited to 15 countries in the Indo-Pacific region. However, TVET is of interest to all countries across regions and continents. The method we have adopted and the measures we have developed could be tested across countries to increase the scholarly contribution to the field of TVET.

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