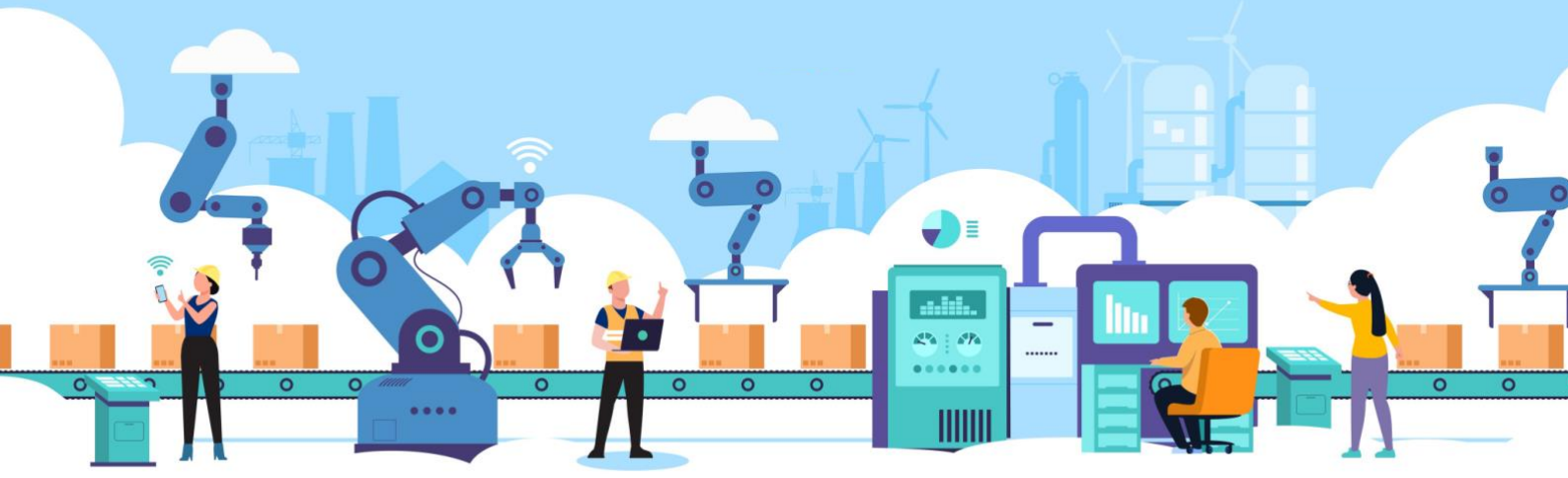
SEAMEO VOCTECH Regional Centre
Brunei Darussalam

REGIONAL REPORT

The Readiness of TVET Institutions for IR 4.0 in Southeast Asia



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This regional report is prepared by:

Dr Paryono
Deputy Director for Professional Affairs cum Research Specialist
SEAMEO VOCTECH

Dr Hartini Haji Mashod
Research Officer
SEAMEO VOCTECH

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Negara Brunei Darussalam
Jalan Pasar Baharu, Gadong BE1318
E-mail: info@voctech.edu.bn
URL: https://voctech.org/

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Acronyms

AI	Artificial Intelligence
AR	Augmented Reality
ASEAN	Association of Southeast Asian Nations
BICPA	Brunei Darussalam Institute of Certified Public Accountants
CCCT	Cosmopolitan College of Commerce and Technology
CQF	Cambodia Qualification Framework
DTAP	Digital Transformation Acceleration Program
DTE	department of Technical Education
DDTVE	Directorate of technical and Vocational Education
FGD	Focus Group Discussion
GIZ	Gesellschaft fur Internationale Zusammenarbeit
GTHs	General and technical high schools
HEIs	Higher Education Institutions
HED	Higher Education for Development
HOM	Higher Official Meeting
IBTE	Institute of Brunei Technical Education
ICT	Information and Communcation Technology
IDP	Industrial Development Policy
IT-BPO	Information Technology-Business Process Outsourcing
ITE	Institue of Technical Education
IoT	Internet of Things
IRF	Industry Reporting Framework
IR 4.0	Industry Revolution 4.0
JCB	Job Centre Brunei
JCHS	JPMC College of Health Sciences
KI	Kemuda Institute
KIGS	Kolej International Graduate Studies
LCB	Laksamana College of Brunei
L3C	LifeLong Learnig Centre
LMS	Learning Management System
MDEC	Malaysia Digital Economy Corporation
MIC	Micronet International College
MOE	Ministry of Education
MOEC	Ministry of Education and Culture
MoEMI	Ministry of Education, Manpower and Industry
MOI	Ministry of Industries
MPEC	Manpower Planning and Employment Council
MoMT	Ministry of Manpower and Transmigration
NAMIC	National Addictive manufacturing Innovation Cluster
NRAC	National Robotics and automation centre
OVEC	Office of the Vocational Education Commission

OERs	Open Educational Resources
PLM	Pusat Latihan Mekanik
PPP	Public-Private Partnerships
RAMI 4.0	Reference Architectural Model for Industry 4.0
RGC	Royal Government of Cambodia
R&D	Research and Development
RMUTT	Rajamangala University of Technology Thanyaburi
SEA	Southeast Asia
SEA-TVET	Southeast Asian Technical and Vocational Education and Training
SEAMEO	Southeast Asian Ministers of Education Organisation
SEAMEO SEAMOLEC	Southeast Asian Ministers of Education Organisation - Open Learning Centre, Indomesia
SEAMEO RECSAM	Southeast Asian Ministers of Education Organisation - Regional Centre for Education in Science and Mathematics, Malaysia
SEAMEO TED	Southeast Asian Ministers of Education Organisation Regional Centre for Technical Education Development, Cambodia
SERI	Smart Education Readiness Index
SIRI	Smart Industry Readiness Index
SIS	School Information System
STEM	Science, Technology, Engineering and Mathematics
SMEs	Small and Medium-sized Enterprises
SMK	*Sekolah Menegah Kejuruan* [Vocational High schools (in Indonesia)]
TAM	Technology Acceptance Model
TESDA	Technical Education and Skill Development Authority, Philippines
TOP	TESDA Online Program
TTIs	TESDA Technology Institutions
TVET	Training and Vocation Education and Training
T&L	Teaching and Learning
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNESCO UNEVOC	United Nations Educational, Scientific and Cultural Organisation and Vocational Education
USB	Universal Serial Bus
UTHM	Universiti Tun Hussein Onn Malaysia
VR	Virtual Reality
WIL	Work Integrated Learning

List of Tables

List of Figures

Table of Contents

Executive Summary

Introduction

The Fourth Industrial Revolution (Industry 4.0 or IR 4.0) presents both challenges and opportunities for a country's workforce, society, and economy. In Southeast Asia, the development and technology adoption across SEAMEO member countries are highly diverse, necessitating varied strategies and approaches for workforce preparation. Despite these differences, the integration of digitalisation through IR 4.0 is an inevitable trend that will redefine the industrial landscape at the national, regional, and global levels. In preparing the current and future workforce, education and training providers, particularly Technical and Vocational Education and Training (TVET) institutions, play crucial roles. Therefore, understanding the current state of readiness for IR 4.0 among TVET institutions in SEAMEO member countries is of paramount importance.

Recognising the integral link between industry and TVET, the Fourth High Officials Meeting on Southeast Asia TVET (4th HOM on SEA-TVET) recommended comprehensive research to assess the readiness of TVET institutions for IR 4.0. In response, SEAMEO VOCTECH coordinated a study with the objectives of: (1) Assessing the readiness of TVET institutions in SEAMEO Member States for IR 4.0, and (2) Soliciting feedback and recommendations from TVET and industry leaders for future development in Southeast Asian countries. This regional study covers nine SEAMEO member countries: Brunei, Cambodia, Indonesia, Malaysia, Lao PDR, Singapore, Thailand, Philippines, and Vietnam.

Methods

Using a mixed-method research approach, quantitative data was collected via a survey questionnaire based on SERI framework developed by the research team. The framework consists of three building blocks: Process, Technology, and Organisation. Each block contains specific pillars and dimensions, as detailed below:

- **Process:** Includes ***Curriculum*** (General/ Transversal Skills, Specific/ Specialised Skills), ***Stakeholder Engagement*** (Collaboration with non-

industry, Collaboration with industry), and ***Teaching & Learning*** (Teaching & Learning Process, Assessment).

- **Technology:** Comprises ***Infrastructure*** (Digital Infrastructure Readiness, Digital Storage), ***Intelligence*** (Automation, Machine Learning, Innovative Analysis) and ***Connectivity*** (Risk and Cyber Security Management, Digital Connectivity).
- **Organisation:** Involves ***Structure & Management*** (Embedded IR 4.0 framework in the organisation's purpose, vision & mission, Policies that guide institution to adapt IR 4.0-related technologies, Plans to implement IR 4.0-related technologies), ***Talent Readiness*** *(*Current workforce is capable to adopt IR 4.0-related technologies, Training plans in place to develop our workforce's capabilities, skills and competencies, Capable task force to drive IR 4.0 integration).

Qualitative data was collected through Focus Group Discussions (FGDs) and interviews with both industry and education representatives to assess current initiatives, strategies, and future plans for adopting IR 4.0. The qualitative findings obtained from the interview and FGD sessions with representatives from TVET institutions and industry stakeholders have been analysed to identify common themes. This analysis provides a comprehensive understanding of the perspectives and insights shared by participants, highlighting critical areas of focus and concern related to the integration of Industry 4.0 within TVET institutions. This approach facilitates the identification of overarching trends and patterns, underscoring the specific needs and priorities of both TVET institutions and industry representatives.

Key Findings

The quantitative findings using the SERI framework (scale of 0 to 4) indicate that the overall readiness of TVET institutions for IR 4.0 in Southeast Asia is **1.98**, categorising them as early adopters or learners. This index comprises:

- **Process: 1.90**
- **Technology: 1.89**
- **Organisation: 2.16**

Comparatively, the worldwide IR 4.0 readiness index for industry using the Smart Industry Readiness Index (SIRI) framework is 1.55.

Detailed examination of the dimensions reveals varying levels of readiness. For instance, in the Curriculum pillar, both General/ Transversal Skills and Specific/ Specialised Skills have readiness indices below 2. Stakeholder Engagement shows engagement at passive and regulatory compliance stages. The Teaching & Learning pillar demonstrates adaptive and independent use of IR 4.0 technology. The Technology block shows readiness below 2, indicating early adoption. TVET institutions are more prepared in digital infrastructure and storage but lag in digital interconnectivity, automation, cyber security, innovative analysis, and machine learning. In the Organisation block, TVET institutions show progress toward IR 4.0 adoption with integration into Vision and Mission, workforce capability, relevant policies, training plans, and implementation plans, although the taskforce capability remains relatively less developed.

The themes that emerged from the FGD sessions with TVET institutions encompass a broad spectrum of issues, including the importance of integrating Industry 4.0 within TVET institutions, policy development and implementation, resource and infrastructure needs, innovation and skills development, alignment with industry needs, gender inequality and inclusivity, partnership and collaboration, and continuous evaluation and adaptation. Meanwhile, the outcomes from the FGD sessions with industry representatives revealed five predominant themes: positive changes and opportunities, challenges and preparedness, cybersecurity and connectivity, skill development and training, and government support.

Recommendations

The findings of this initial study can serve as benchmarks for institutions or countries to chart their roadmaps or action plans. Within these action plans, institutions can identify areas requiring immediate action or improvement. The impact of these plans can then be assessed and monitored using the same tool, the SERI assessment

matrix, in the following years. To advance IR 4.0 adoption in TVET institutions, the following actions are recommended:

1. **Enhance Digitalisation Efforts:** Continuous efforts should be made to adopt digitalisation and IR 4.0 in both TVET institutions and industry. Experience sharing and collaboration between these sectors can synergise efforts and reduce mismatches.

2. **Utilise SERI as a Guideline:** Employ the SERI framework for gauging readiness and creating a roadmap toward IR 4.0. This includes policy briefs for policymakers and detailed action plans with timelines and specific activities.

3. **Policy Recommendations for ASEAN Ministries of Education:**
    i. Adopt SERI as a tool for assessing and monitoring the digital readiness of educational institutions.
    ii. Use SERI for regular monitoring and as part of accreditation components.

4. **Self-Assessment for TVET Institutions:**
    i. Use SERI for self-assessment to gauge current readiness levels.
    ii. Develop strategies and action plans to progress to higher levels of IR 4.0 adoption.

1.0 Introduction

1.1 Background of the project

The Fourth Industrial Revolution (Industry 4.0 or IR 4.0) encompasses transformative technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data analytics, and advanced robotics. These technologies are poised to enhance productivity, innovation, and efficiency across various sectors. Industry 4.0 holds promise in generating novel value streams for individuals, enterprises, industries, and nations. The affordability, accessibility, and user-friendliness of Industry 4.0 applications and solutions are expanding. Globally, there is consensus on their capacity to optimise the utilisation of labour, capital, and natural resources, thereby fostering enhanced efficiency and productivity. Projections suggest that these technological advancements could potentially contribute up to US$625 billion to the ASEAN economy by 2030 (UNDP, 2020).

The stages of development and technology adoption across SEAMEO member countries exhibit a substantial degree of diversity, necessitating the implementation of varied strategies and approaches for workforce preparation. This diversity is attributed to a range of factors including economic disparities, varying levels of technological infrastructure, educational system differences, and distinct socio-political contexts within each member country. Consequently, these factors call for a nuanced and context-specific approach to workforce development that can cater to the unique needs and capacities of each country. Notwithstanding these differences, the integration of digitalisation through IR 4.0 is an inevitable trend that is set to redefine the industrial landscape globally.

The Southeast Asian economies are predominantly characterised by small and medium-sized enterprises (SMEs), which play a crucial role in driving economic activity in the region. The response of these enterprises to digitalisation is highly variable, influenced by factors such as industry-specific needs, company size, financial resources, and strategic vision. This variability makes it challenging to predict the extent to which IR 4.0 will disrupt industries and employment in Southeast Asia. However, recent research has consistently highlighted a significant shortage of

adequately skilled workers as a critical bottleneck to the future economic development of ASEAN member states. This skills gap poses a substantial barrier to fully exploiting the potential benefits of IR 4.0 for sustained economic growth and competitiveness.

As such, understanding the current state of readiness for IR 4.0 among TVET institutions in SEAMEO member countries is of paramount importance. This knowledge is critical for governments and industry stakeholders to formulate and implement effective policies and strategies that can facilitate a seamless transition to this new industrial paradigm. The education sector faces the imperative of adapting to rapid technological advancements and the advent of Industry 4.0. These adaptations particularly require vocational educators to enhance their forward-thinking capabilities. Aoun (2017) emphasises the necessity for educators to cultivate 21st-century skills and a nuanced understanding of literacy that encompasses proficiency in data, technology, and humanities (Pratita et al., 2020). In this context, TVET is increasingly recognised as a pivotal mechanism for addressing the skills gap and reducing unemployment. By providing relevant, high-quality education and training, TVET equips individuals with the necessary skills to navigate the evolving job market.

The current body of research on the readiness of industries and TVET institutions for IR 4.0 in Southeast Asia is notably limited. Consequently, there is a significant gap in our understanding of the status of both industries and TVET institutions regarding their preparedness for IR 4.0. Such information will enable the formulation of effective policies and programmes that can enhance the preparedness of the workforce in Southeast Asia, ensuring that the region can fully capitalise on the opportunities presented by IR 4.0. This lack of comprehensive data hampers the ability to devise effective policies and strategies to facilitate the transition to IR 4.0 within the region.

TVET has become a priority on the political agendas of SEAMEO and ASEAN member states. Recognising the integral link between industry and TVET, the Fourth High Officials Meeting on Southeast Asia TVET (4th HOM on SEA-TVET) recommended the conduct of comprehensive research to assess the readiness of TVET institutions for IR 4.0. In response, SEAMEO VOCTECH proposed conducting a study to assess the preparedness of TVET institutions for IR 4.0 across Southeast Asia.

The objectives of this study are as follows:

- **To assess the readiness for IR 4.0 of TVET institutions in SEAMEO Member States**
- **To solicit feedback and recommendations from TVET and industry leaders for the future development in Southeast Asian countries**

This regional report consolidates findings obtained from the participating countries, namely Brunei, Cambodia, Indonesia, Malaysia, Lao PDR, Singapore, Thailand, Philippines, and Vietnam. It serves as a comprehensive synthesis of insights garnered through extensive research and analysis conducted across these diverse Southeast Asian nations. By collating data, trends, and perspectives from each country, the report aims to provide an overview of the current state of affairs regarding Industry 4.0 adoption, policies, initiatives, and challenges within the region.

1.2 Current landscape of IR 4.0 in the participating countries

This section examines the current initiatives, policies, roadmaps, and programmes implemented by each country in response to and adoption of Industry 4.0. It aims to analyse the specific actions taken by these nations to integrate IR 4.0 technologies into their industrial frameworks, focusing on efforts to enhance productivity, promote innovation, and prepare the workforce for the rapidly evolving digital economy.

1.2.1 Brunei Darussalam

Brunei Darussalam is actively pursuing a comprehensive approach to digital transformation through its Digital Economy Master Plan 2025. This outlines the country's commitment to embracing digital transformation and preparing its workforce and educational institutions for the challenges and opportunities of the IR 4.0. The Digital Economy Master Plan 2025 is designed to align with the broader goals of Brunei Vision 2035 (Wawasan Brunei, 2035). This alignment signifies a holistic approach to achieving high quality of life, a highly educated and skilled workforce, and a sustainable and dynamic economy. Similarly, The Ministry of Education's Digital Transformation Plan 2023–2027 was developed with the aim to integrate digital

technologies into the education sector. By focusing on integration, resource improvement, educator training, and digital literacy standards, the plan aims to create a digitally-enabled education environment that aligns with the broader national vision. This plan reflects a commitment to leveraging digital technologies to enhance the education sector in Brunei. Overall, the initiatives in Brunei to enhance the readiness of educational institutions for Industry 4.0 demonstrate a commitment to preparing the workforce for the evolving technological landscape. By updating curricula, training programmes, and infrastructure, these institutions are playing a key role in ensuring that individuals are well-prepared for the challenges and opportunities presented by advanced technologies in the industrial sector.

The establishment of multiple private higher education institutions reflects a diversification of educational opportunities in Brunei, catering to various fields of study and disciplines. The establishment of institutions like Lifelong Learning Centre and the focus on quality lifelong learning programmes, including upskilling and reskilling, demonstrate a commitment to improving the employability of the Brunei workforce. These initiatives align with the goal of promoting and improving opportunities for lifelong learning for Bruneian citizens. In summary, the education landscape in Brunei involves a multi-faceted approach, encompassing TVET, higher education, and lifelong learning, with a focus on adapting to the needs of Industry 4.0 and promoting continuous learning opportunities for individuals of all ages.

1.2.2 Cambodia

Cambodia envisions achieving upper-middle-income status by 2030 and becoming a high-income country by 2050, as outlined in the Royal Government of Cambodia's Rectangular Strategy. The country has experienced economic growth in recent years, marked by increased foreign direct investment (FDI) and a demographic advantage with a youthful population (Castañeda-Navarrete et al., 2019). As part of the initiatives, the Industrial Development Policy (IDP) 2015–2025 put emphasis on the importance of utilising new technologies to enhance industrial value, diversify exports, and strengthen small and medium-sized enterprises (SMEs) for the realisation of this vision. Several initiatives are undertaken to foster technology and innovation, including

the strategic framework for Cambodia's digital economy that aims to transition into a digital economy by 2023. The successful pursuit of this goal hinges on Cambodia's adeptness in mastering and leveraging emerging digital technologies, with Industry 4.0 presenting opportunities for advancement. This includes the potential for technological trends to drive Cambodia toward a knowledge-based economy and the critical role of technology infrastructure in industrial diversification, productivity growth, and competitiveness (CDRI, 201; Chhem et al., 2019).

To achieve sustainable and inclusive growth, prioritisation is crucial in tertiary education and vocational training to develop a highly qualified and skilled workforce capable of meeting the evolving demands of rapid industrialisation. Digitalising and transforming TVET providers, both institutes and centres, is imperative to keep pace with innovation. However, the current state of digital education in Cambodia poses challenges to competitiveness at the regional level, with insufficient resources for Industry 4.0 skills at TVET institutions in terms of infrastructure, facilities, internet and cloud technology, instructor expertise, curriculum, and supporting policies (MoEYS, 2015; MPT, 2022). TVET instructors at these institutions face limitations in catching up with Industry 4.0 skills and digital transformation (MoLVT, 2017). The Cambodian government recognises the significance of digitalisation in education policy, not only for enhancing the quality of education through student-centred approaches but also as a vital prerequisite for social and economic development. Reforms in Cambodia's education system, integrating information and communication technology (ICT), are essential for the adoption of student-centred learning and the advancement of local human resources and economic performance, positioning Cambodia alongside other ASEAN countries (Heng, 2022).

1.2.3 Indonesia

Over the past two decades, Indonesia has experienced significant technological advancements, transforming the labour market. Despite increasing awareness of these changes, a comprehensive understanding of the future workforce's capacity and skills remains limited. Additionally, the readiness of higher education institutions,

including universities, institutes, and polytechnics, to prepare for a future-ready workforce remains unclear (Pratita et al., 2020). To address these concerns, the Indonesian government has initiated various policies and programmes.

In anticipation of future demands, the Ministry of Industry has spearheaded the 'Making Indonesia 4.0' initiative, a roadmap designed to cultivate a technology-literate workforce responsive to the needs of emerging industries (Pratita et al., 2020). Launched to expedite the implementation of Industry 4.0 technologies in the country, this comprehensive roadmap encompasses key areas such as sustainability, support for technology startups, and the promotion of a circular economy. The focal points of the Making Indonesia 4.0 roadmap include Artificial Intelligence, Internet of Things, Enterprise Wearables, Advanced Robotics, and 3D Printing, all aimed at fostering the growth of the digital economy and providing incentives for the industry (Zahra, 2023).

Additionally, the Education 4.0 initiative in Indonesia aims to enhance the overall quality of the country's human resources. This educational transformation recognises the importance of establishing an Education 4.0 system capable of influencing changes in both local and global education landscapes. Envisaging a shift towards technology-based learning, the plan aims to produce human resources equipped to function effectively in the twenty-first century. Achieving this goal requires a shift in educators' mindsets, the development of technology-focused curricula, and the implementation of programmes aimed at enhancing the technological capabilities of human resources, such as Indonesia's talent mobility programme for professionals (Yanuarto et al., 2020).

1.2.4 Lao PDR

The Government of Lao PDR has outlined a vision to transform its economy into a digitalised powerhouse, targeting a significant increase in GDP from 3 percent to 10 percent by 2024 (World Bank, 2022). This vision is encapsulated in the formulation of key digital policies, including the National Digital Economic Development Plan for 2021-2040, the National Digital Economic Development Strategy for 2021-2030, and

the National Digital Socio-Economic Development Plan (NSEDP) for 2021-2025. A crucial component of these strategies is the digital human resource development strategy, which aims to (1) enhance knowledge and skills related to digital technology, encompassing the Internet, ICT equipment, curriculum improvement, and online instruction; (2) cultivate a digital-savvy workforce to meet labour market demands; (3) narrow the digital utilisation gaps among urban, district, and remote areas; and (4) encourage digital utilisation for youth-led business start-ups (National Assembly, 2021).

The development of digital skills, particularly at the tertiary level, is identified as a key driver for the realisation of a digitalised economy in Lao PDR. The Ministry of Education and Sports (MoES) and the Ministry of Labour and Social Welfare are the two primary government agencies responsible for fostering skills and preparing the workforce for the digital era (World Bank, 2022). The 9th NSEDP, covering the period 2021-2025, mandates the integration of ICT skills in teaching and learning at the secondary and tertiary levels. At the primary level, it emphasises the prioritisation of cognitive and socioemotional skill development for all students (Government of Lao PDR, 2021, as cited in Nietschke & Dabrowski, 2023). Consistent with the NSEDP, the MoES specifically focuses on utilising ICT to enhance education quality at the upper secondary and tertiary levels in alignment with the demands of the labour market. Furthermore, the MoES is in the process of formulating its own ICT policy as part of the National ICT Policy (Nietschke & Dabrowski, 2023).

Despite the high demand for digital skills training in Lao PDR, there is currently no integration of digital skills training within the curricula of TVET and Non-formal Education. This presents both challenges and opportunities in the context of Industry 4.0, where addressing the skills gap becomes crucial for the success of industries in adapting to digitalisation. Recognising this, there is a pressing need to align TVET programmes with the skills demanded by the evolving industrial landscape to ensure that graduates are well-prepared for the demands of Industry 4.0. Lao PDR's legislative actions and strategic plans reflect a comprehensive approach to digital economic development, emphasising the importance of cultivating digital human resources. The strategies encompass a range of initiatives, from skills promotion and

labour market alignment to reducing digital disparities and fostering youth entrepreneurship through digital utilisation. These initiatives play a pivotal role in driving Lao PDR's digital economy and ensuring inclusive and sustainable development in the coming years.

1.2.5 Malaysia

Malaysia has been actively adopting IR 4.0 to promote economic growth, boost competitiveness and enhance numerous economic sectors, much like many other nations across the world. Despite the government's projections of IR 4.0 adoption, on-the-ground surveys indicate a lack of readiness (Cheok & Ran, 2023), TVET institutions in Malaysia are facing challenges in preparing for IR 4.0 (Hamid et al., 2023).

TVET sector plays a crucial role in preparing the population for IR 4.0, but it is facing issues such as falling enrolments and competency deficiencies among instructors (Kuntadi et al., 2022). Additionally, there is a need to improve the digital skills of TVET students to meet the demands of the digitalised industry (Halik Bassah & Mohd Noor, 2023; Kuntadi et al., 2022). Employability skills, including social and communication, technological literacy, teamwork, and leadership, are also important for TVET graduates to succeed in the industry (Nurjana & Ana, 2022). To address these challenges, strategic planning, collaboration between TVET institutions and industries, continuous professional development of teachers, and the application of innovative learning strategies are necessary.

Malaysia's Industry 4.0 initiatives, as outlined in the Industry4WRD policy, demonstrate a comprehensive approach to technology adoption, workforce development, and fostering innovation. The readiness assessment and focus on key sectors underscore the government's commitment to positioning Malaysia as a competitive player in the global digital economy. The policy highlights the importance of research and development (R&D) in advancing Industry 4.0, promotes collaboration between industry and academia to drive R&D efforts, develop new technologies, and create a supportive ecosystem for innovation. The policy focuses on key areas,

including technology adoption, workforce development, innovation ecosystems, and regulatory frameworks.

Preparing TVET for IR 4.0 in Malaysia requires a multi-faceted approach, including strategic planning, collaboration, professional development, and innovative teaching methods. These efforts are essential to ensure that TVET institutions are equipped to meet the evolving needs of the industry and provide students with the necessary skills for success in the digital era. The readiness of TVET institutions for Industry 4.0 is identified as a critical factor in ensuring a skilled workforce capable of adapting to the evolving industrial landscape. TVET institutions can enhance readiness through strategies such as curriculum updates, faculty development, industry collaboration, infrastructure investments, fostering innovation, and entrepreneurship.

Malaysia's efforts to accelerate digital transformation, particularly for small and medium-sized enterprises (SMEs), through the Digital Transformation Acceleration Program (DTAP). DTAP was introduced as a programme aimed at accelerating the digitalisation of small and medium-sized enterprises (SMEs) in Malaysia. The programme is strategically aligned with the challenges and opportunities presented by the Fourth Industrial Revolution (IR 4.0), emphasising the importance of digital adaptation. DTAP in Malaysia represents a concerted effort to empower SMEs through financial support, training, and advisory services, fostering their digital transformation. The programme aligns with broader national strategies aimed at preparing businesses for the challenges and opportunities presented by the Fourth Industrial Revolution. The support provided through DTAP contributes to the overall digital readiness and resilience of SMEs in the Malaysian business landscape. Other establishment of key initiatives in Malaysia are the National Robotics and Automation Centre (NRAC) and the Malaysian government established the National Robotics and Automation Centre (NRAC) and the National Additive Manufacturing Innovation Cluster (NAMIC) to support and drive research and development in the fields of robotics, automation, and additive manufacturing. Various initiatives by the Malaysia Digital Economy Corporation (MDEC) to enhance digital skills, promote innovation, and prepare individuals for the demands of the digital economy.

1.2.6 Philippines

The National Digital Strategy launched by the Philippines government encompassed a comprehensive national Digital Strategy, emphasising the importance of digitalisation across various sectors of the economy. An Artificial Intelligence (AI) Roadmap has been introduced, which serves as a strategic plan to enhance AI capabilities within the country. There is a focus on galvanising investment in digital infrastructure and Industry 4.0 capacity. This highlights the recognition of the pivotal role played by robust digital infrastructure in the context of the fourth industrial revolution.

The initiatives aim to build high-skill and knowledge-intensive capabilities within the workforce. This involves upskilling and reskilling programmes to equip workers with the skills required for the evolving technological landscape. The AI Roadmap includes plans to establish a flagship National Centre for AI Research. This centre is designed to serve as a collaborative platform for partnerships with international tech companies like Amazon and Google. The objective is to identify and implement AI applications across various industries. The effective execution of these initiatives is seen as crucial for sustaining economic growth and maintaining international competitiveness, especially in sectors like the $26 billion IT-Business Process Outsourcing (IT-BPO) industry. Sectors like IT-BPO and manufacturing are highlighted as vulnerable to automation and reshoring of jobs. The initiatives aim to address these vulnerabilities by strategically leveraging local competencies in areas such as healthcare, accounting, and data analysis.

The emphasis is on transitioning towards higher value, knowledge-based activities. The Philippines's strategic approach involves a holistic integration of digital strategies, AI development, and skill enhancement to position itself as a competitive player in the global technological landscape, while addressing potential challenges and job vulnerabilities. TESDA has made strides over the years, questions around its appropriate role, endemic resource constraints, and organisational capacity weigh on its ability to respond to Industry 4.0. TESDA's main challenge is how to redefine its

role as the authority of TVET in the context of fast-changing environments and the realities of its own organisational resources.

1.2.7 Singapore

Singapore integrates innovation and creativity into its education system, preparing students for future challenges in a rapidly evolving world. The education system in Singapore promotes lifelong learning, recognising the importance of continuous skill development throughout one's life. Singapore's education system provides various pathways for further education and career development, offering flexibility for students to pursue different routes based on their interests and strengths. Singapore's Ministry of Education (MOE) is responsible for overseeing the education system. Singapore's education system features a well-structured curriculum designed to provide a comprehensive and high-quality education. Singapore's education system is characterised by its commitment to academic excellence, a meritocratic approach, a well-structured curriculum, highly qualified teachers, and a focus on STEM subjects and innovation. The system is designed to equip students with the skills and knowledge needed for success in the future while providing flexibility for diverse pathways in further education and career development.

Singapore placed a strong emphasis on TVET as a crucial component of its workforce development and economic growth strategy. Singapore has a robust TVET policy that plays a vital role in developing a skilled workforce to support economic growth and social progress. The government, through its SkillsFuture initiative, places significant emphasis on enhancing TVET opportunities and promoting lifelong learning for the continuous relevance of skills and employability of the workforce. The TVET ecosystem in Singapore is characterised by strong partnerships between industry and educational institutions. These partnerships ensure that training programs are aligned with industry needs, enhancing the practical relevance of the skills imparted. The government actively supports the upgrading and re-skilling of workers through subsidies and grants. This support makes TVET an attractive option for individuals seeking vocational training and continuous skill development.

The Institute of Technical Education (ITE), Polytechnics, and other specialised training institutes play a key role in offering a wide range of career-based skills courses and apprenticeships. These institutions aim to equip individuals with practical skills and industry-relevant knowledge, ensuring that graduates are well-prepared for the demands of the workforce. Curriculum and training programmes offered by TVET institutions are designed in close collaboration with industry partners to ensure alignment with current and future industry needs. The focus on continuous learning, practical skills development, and alignment with industry needs reflects the country's commitment to building a highly skilled and adaptable workforce to meet the challenges of a dynamic global economy.

1.2.8 Thailand

Thailand's TVET system, governed by the Office of the Vocational Education Commission (OVEC) under the Ministry of Education, which is responsible for developing nationwide policies, curricula, and standards for TVET institutions. The TVET curriculum in Thailand is designed to be responsive to labour market demands and industry needs. Encompasses various disciplines, including engineering, manufacturing, agriculture, hospitality, and healthcare. The curriculum also includes a mix of theoretical knowledge and practical hands-on training to ensure students are well-equipped for their chosen careers. Thailand has implemented a dual vocational education system that combines classroom learning with on-the-job training. This approach allows students to gain real-world experience by working directly in the industry under the guidance of experienced mentors.

Thailand's TVET system is designed to provide a diverse range of vocational education and training options, with a focus on responsiveness to industry needs and practical skill development. The inclusion of dual vocational education emphasises the importance of hands-on experience for students and strengthens the connection between education and the workforce. The Thai government actively promotes collaboration between TVET institutions and the private sector. Public-private partnerships play a crucial role in shaping the TVET curriculum to accurately match

industry needs. Companies contribute by providing input on skill requirements and participating in internship programs, ensuring graduates possess sought-after skills.

The Thai government is expected to continue investing in and reforming the TVET system to enhance its effectiveness and responsiveness to the dynamic job market. Addressing challenges such as changing perceptions, securing funding, and maintaining alignment with industry needs will be crucial for the continued success of the TVET system. Closer collaboration between the public and private sectors is emphasised to strengthen the TVET system further.

1.2.9 Vietnam

Vietnam's commitment to actively participating in the fourth industrial revolution through Resolution No.52. Government Policy Emphasis where the Party General Secretary and President have signed Resolution No.52, reflecting the commitment of the government to implementing policies that facilitate Vietnam's active participation in Industry 4.0. Vietnam has intensified efforts in the development and application of science, technology, and creative innovation in recent years to access and contribute to Industry 4.0. Despite the progress, the level of active participation in Industry 4.0 is perceived as still low, prompting the need for further measures. Resolution No.52 aims to "make full use of opportunities brought about by Industry 4.0," indicating a strategic approach to leverage the benefits of the fourth industrial revolution. Overall, Resolution No.52 reflects Vietnam's aspirations to harness the opportunities presented by Industry 4.0, enhance innovation, and boost its digital economy. The goals outlined in the resolution indicate a strategic vision for positioning Vietnam competitively in the evolving landscape of the fourth industrial revolution.

The Vietnamese government is taking steps to address the Industry 4.0, emphasising vocational training programmes and technical education. Efforts include utilising the government's budget, subsidising vocational training tuition fees, and encouraging foreign direct investment to bring in expertise and technology. Vietnam has undergone significant economic growth, leading to socio-economic changes and an increase in

living standards. Challenges arise from the shortage of skilled workers, with only 11.6% considered highly skilled. This shortage impacts various sectors, including technology, manufacturing, and services. Despite progress in expanding access to education, there is a need to improve the quality of education to align it with job market demands. A mismatch between the skills taught in schools and those required by industries contributes to a significant skills gap and high unemployment rates. Opportunities for collaborations and partnerships between TVET institutions and relevant industries can be identified. Facilitating knowledge transfer, internships, and industry involvement in curriculum development can ensure that TVET programmes stay aligned with the evolving needs of industries.

1.3 Development of Smart Education Readiness Index (SERI) Framework

The development of the SERI Framework was underpinned by a comprehensive and systematic review of multiple concepts and frameworks pertinent to Industry 4.0. This process involved an extensive review of industry reports, models, and contributions from various industry stakeholders. In total, seven distinct frameworks were analysed and integrated as foundational references in the development of the SERI Framework. This rigorous approach ensured that the SERI Framework is comprehensive and reflective of the latest advancements and best practices in Industry 4.0. The following subsection will briefly explain the frameworks being used as reference in the development of SERI framework.

1.3.1 Self-assessment of industry readiness

The Impuls (2015) Readiness Model underpins a thorough self-evaluation and comparative analysis framework. This model's Online Self-Check tool enables organisations to assess their Industry 4.0 readiness across six critical dimensions: strategy and organisation, smart factory, smart operations, smart products, data-driven services, and employees. Designed to explore essential aspects, the model examines structural attributes of companies, general questions about Industry 4.0, the extent to

which companies satisfy Industry 4.0 dimensions, and the motivators and obstacles encountered on the journey to Industry 4.0. These evaluations categorise corporations into 'newcomers,' 'learners,' or 'leaders,' providing a nuanced understanding of their Industry 4.0 maturity.

The model comprises six primary dimensions and 18 fields. The inner circle focuses on the six dimensions (strategy and organisation, smart factory, smart operations, smart products, data-driven services, and employees), each further divided into fields and operationalised with relevant indicators. The outer circle delineates the fields associated with each dimension. The 18 fields are measured using indicators that classify organisations into levels ranging from 0 (outsider), 1 (beginner), 2 (intermediate), 3 (experienced), 4 (expert) and 5 (top performer).

1.3.2 Malaysia Industry4WRD

The Industry4WRD model, developed by the Ministry of International Trade and Industry in Malaysia, comprises three shift factors, eight thrusts, and twenty-one dimensions. The Industry4WRD Readiness Assessment is designed to help companies evaluate their competencies and readiness to adopt IR 4.0 technologies and procedures. This programme is open to enterprises in the manufacturing and IT-related services sectors within Malaysia and offers several benefits, including the identification of areas for improvement in IR 4.0 adoption and the opportunity to apply for financial incentives (MPC, n.d.).

The model's inner circle features three pivotal shift factors: People, Process, and Technology. The first shift factor, People, focuses on both individuals and the organisation as a whole, emphasising strategies for developing a skilled and appropriate workforce. The second shift factor, Process, pertains to the management systems used in business operations, supply chain management, and product lifecycle. This factor highlights the importance of intelligent and strategic public–private partnerships, security, sustainability, and product co-creation. The third shift factor,

Technology, stresses the use of intelligent, interconnected, and automated technologies (Saari, n.d.).

1.3.3 Labtech Digital TVET Framework

The Labtech Digital TVET framework, developed by Labtech International, emphasises the critical need for investment in teacher training, digital platforms, high-quality content, and the establishment of networks that transcend institutional boundaries (McKee, n.d.). This framework is structured into three outer layers: InfraStructure, InfoStructure, and InfoCulture, each containing four internal dimensions that detail the sub-components. The InfraStructure layer encompasses hardware, integration and support, connection, and bandwidth. These components ensure that the foundational physical and technical aspects are robust and capable of supporting digital initiatives. The InfoStructure layer includes software, platform, content, and assessment, focusing on the digital tools and resources necessary for effective teaching and learning. Finally, the InfoCulture layer covers curriculum, policy, capacity building, and change management, addressing the educational and organisational strategies required to foster a culture conducive to digital transformation.

1.3.4 TVET College Readiness

The study conducted by Makgato (2019) presents empirical findings from three TVET colleges located in one province within South Africa. The empirical part focused on vocational pedagogic and didactic practices, workshop material and equipment for practical training, work-integrated learning and integration of theory and practice in vocational subjects. The study's results reveal both congruent patterns and conflicting outcomes with prior empirical investigations. Within the category of pedagogical and didactic practices, a significant majority of the students expressed agreement with the notion that the VET pedagogy is geared towards augmenting their ability to think independently. This finding is consistent with the research conducted by Reeson et al.

(2016), which highlights the necessity for educators to adopt a distinct pedagogical approach and skill set in light of the emergence of Industry 4.0.

Furthermore, the results pertaining to the perspectives of students regarding the amalgamation of theoretical and practical aspects in academic disciplines indicate that a significant proportion (75.0%) of students concur that they encounter obstacles in acquiring the essential competencies and expertise requisite for social and economic development. Additionally, a majority of the students concurred on the significance of collaboration in vocational education and training. The aforementioned results offer a comprehensive analysis of students' perspectives regarding the preparedness of their institutions for IR 4.0. These outcomes may serve as a point of reference for universities and policymakers in devising suitable tactics to facilitate the production of TVET graduates who are equipped for the demands of the future.

1.3.5 Readiness of Public TVET for the IR 4.0

Denhere and Moloi (2021) conducted a study in South Africa to identify various indicators for evaluating the readiness of TVET colleges for IR 4.0. The investigation included 26 public TVET institutions across nine provinces of South Africa. The study assessed 14 specific indicators related to the institutions' preparedness for effective functioning in the IR 4.0 environment. The findings indicate that while public TVET institutions in South Africa have made initial strides toward IR 4.0 readiness, they have not yet achieved full preparedness. These efforts represent a significant step forward, but further development and implementation of strategies are required to fully equip these institutions for the demands of Industry 4.0.

1.3.6 E-Learning Readiness

Chapnick (2000) introduced the E-learning Readiness Model, designed to assess the readiness of individuals within an institution or organisation to adopt e-learning. Chapnick identifies multiple factors that must be considered to evaluate this readiness comprehensively. The model includes a detailed list of 66 factors, organised into eight

distinct categories. Unlike previous research, Chapnick's approach offers a range of options for each query, requiring managers to select the response that best represents their organisation's circumstances. According to Aydin and Tasci (2005), this model not only facilitates an evaluation of an organisation's e-learning readiness but also helps identify areas needing improvement and those that have been successful.

1.3.7 Singapore Smart Industry Readiness Index

The Smart Industry Readiness Index (SIRI) is a comprehensive framework developed to support manufacturers in initiating, expanding, and sustaining their manufacturing transformation efforts, irrespective of their size or industry sector. This framework was created through a collaborative effort with a multinational testing, inspection, and certification corporation and subsequently reviewed and endorsed by a panel of experts from both industry and academia. The SIRI Framework and Assessment Matrix is based on the Reference Architectural Model for Industry 4.0 (RAMI 4.0), established by Platform Industrie 4.0, a leading global Industry 4.0 network (SEDB, 2020).

The SIRI Framework consists of three distinct layers. The uppermost layer includes the three core building blocks of Industry 4.0: Process, Technology, and Organisation. These foundational elements are supported by eight pillars, representing crucial aspects that corporations must focus on to achieve future readiness. The final layer includes 16 dimensions that organisations need to consider when evaluating the current state of their development. The assessment matrix within the SIRI framework serves as a tool for evaluating and measuring performance based on predetermined criteria. This self-diagnostic tool is designed to help companies worldwide assess the current state of their factories, facilitating a structured approach to identifying areas for improvement and advancement.

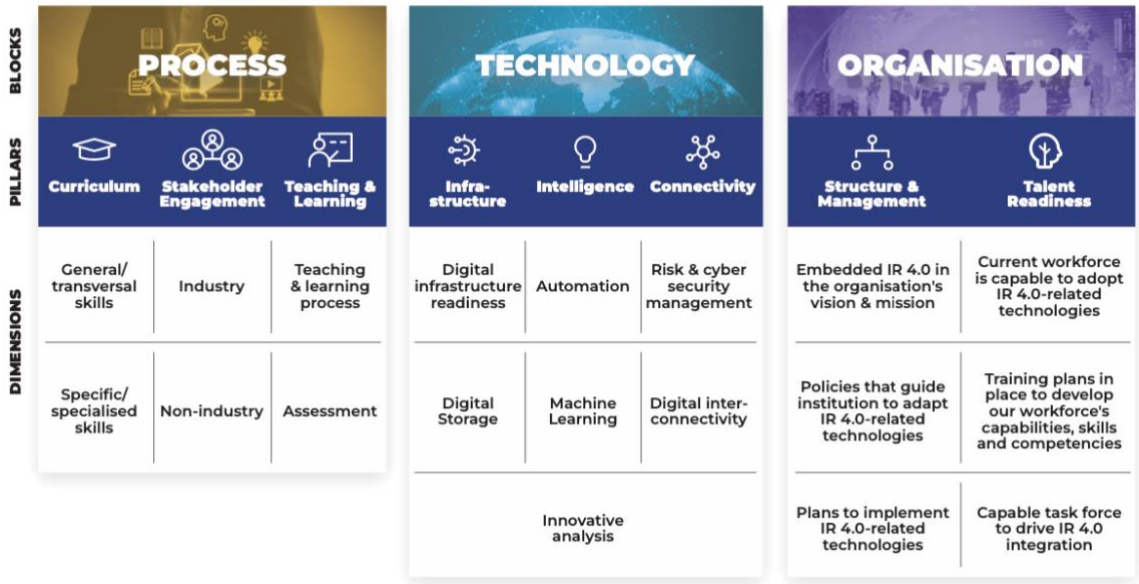
1.3.8 Approaches for development of SERI framework:

1. The process of conducting desk reviews involves the identification, selection, and analysis of pertinent frameworks that assess the readiness of industries and educational institutions. As previously stated, and analysed in the preceding section, various extant frameworks pertaining to the IR 4.0 were evaluated; encompasses of articles and publications.
2. Training and workshops were conducted with researchers from nine SEAMEO member countries and partners to create a framework and tools that are appropriate for evaluating the preparedness of TVET institutions for the IR 4.0. This research project involves the participation of 24 researchers from various SEAMEO sister centres, universities, governmental agencies, and entities. Two workshops were convened to discuss and develop framework and assessment tool to measure the preparedness of TVET institutions for IR 4.0. The first workshop was conducted in a virtual format on 21 – 22 September 2022, with a focus on deliberations pertaining to the framework. The second workshop was held at SEAMEO VOCTECH from 8 – 10 November 2022. The subsequent workshop involves the completion of the research framework and the creation of an assessment tool for the survey questionnaire, as well as the formulation of questions for the focus group discussion.
3. Following the workshops, the framework and assessment tool were pilot tested in nine ASEAN countries by the corresponding researchers. The pilot study yielded 50 responses and analysis indicates a high level of reliability in the measurements utilised. The feedback and suggestions offered by the researchers and participants from the country provide opportunities for enhancing the framework and assessment tool.
4. Before commencing data collection, the enhanced iteration of the survey was disseminated to industry experts for their final review. The SERI framework and assessment matrix were finalised by taking into consideration the feedback received from industry experts.

Following a comprehensive review of the relevant frameworks, extensive deliberation among the research team, and consideration of feedback from partners, a framework

has been established for evaluating the preparedness of TVET institutions for IR 4.0. The Smart Education Readiness Index (SERI) framework is derived from the SIRI framework (SEDB, 2020). The SIRI framework has been designed to evaluate the preparedness of the industry, whereas the SERI framework has been adapted to suit the educational context, thereby enabling its application in assessing the readiness of diverse educational institutions.

Figure 1. SERI Framework developed by SEAMEO VOCTECH's research team.



SERI framework consist of three building blocks: Process, Technology, and Organisation. Under these blocks there are eight pillars contributing to the development of TVET system in line with industrial requirements. The pillars under Process are curriculum, stakeholders' engagement and teaching and learning; the pillars under Technology are infrastructure, intelligence, and connectivity; and the pillars under Organisation are structure and management, and talent readiness. Under each pillar, there are several dimensions which will be assessed using an assessment matrix developed by the research team from SEAMEO VOCTECH. Overall, there are 19 dimensions as depicted in the SERI framework. Each of this dimension is defined and described according to the level of adoption from the lowest level of adoption (band 0) to the highest level (band 4).

1.4 Methodology

The study employed two main assessment tools: surveys and focus group discussions (FGDs) or interviews. The survey served as the main instrument for data collection, while the FGDs or interviews were used to complement and enhance the survey findings. The survey was divided into four sections: demographic information, Process-related questions, Technology-related questions, and Organisation-related questions. To assist respondents in completing the survey, institutions were provided with an assessment matrix for each dimension. This matrix included detailed item questions that offered additional information, thereby facilitating a more accurate and thorough response. This ensures that the study maintains a clear and structured approach, providing comprehensive insights into the readiness of institutions for Industry 4.0 and enabling them to chart a strategic path forward.

The population for this study comprises all formal TVET institutions at both secondary and postsecondary levels within the SEAMEO Member Countries. Formal TVET institutions are defined as those offering TVET programmes that lead to formal certification, such as certificates and diplomas, but below the bachelor's degree level. This includes institutions aligned with the International Standard Classification of Education (ISCED) levels 3, 4, and 5, which correspond to upper secondary education, post-secondary non-tertiary education, and short-cycle tertiary education, respectively. The specific sampling methods were determined by country researchers to ensure relevance and applicability to their unique contexts. It is important to note that these techniques were not intended for generalisation across all institutions but rather to provide targeted guidance for the participating entities.

The FGDs or interviews are complementary to the main data collection tool—survey for TVET institutions. This qualitative approach is not intended as a follow-up to the questionnaire, but rather to supplement and provide alternative viewpoints from industry players and representatives of TVET institutions. FGD is using constructivist (qualitative) angle which is more open and flexible compared to positivist (quantitative) angle.

The FGD or interview allowed the researchers to obtain general understanding from the industry and TVET representatives in terms of their: (1) *Reactions*, (2) *Specific Responses* and (3) *Expectations toward IR 4.0*. It is compulsory for the country researchers to **include questions** on *Reactions* and *Expectations toward IR 4.0* but may **select relevant questions** under *Specific Responses* depending on the stage of IR 4.0 adoption. The Specific Responses cover (a) strategy and leadership, (b) client experience (if any), (c) operations or processes (if adopted), (d) products/services and innovations (if any), and (e) people (management and employees).

The specific objectives of FGD for **industry** representatives:

1. To assess general reactions of industry players as to whether they are optimistic about what IR 4.0 could bring to their companies, innovations that may happen, feelings discomfort or otherwise and insecure or otherwise of IR 4.0.
2. To understand industry's specific responses to IR 4.0 in any of the followings: a) strategy and leadership, (b) client experience, (c) operations, (d) products/services and innovations, and (e) people (management and employees).
3. To gauge industry expectations toward IR 4.0. implementation, such as on work processes, skills needed, and roles of employees.

The specific objectives of FGD for **TVET institutions** representatives:

1. To assess general reactions of education and training providers as to whether they are optimistic about what IR 4.0 could bring to their institutions, innovations that may happen in schools or colleges, feelings discomfort or otherwise and insecure or otherwise with the present of IR 4.0.
2. To understand TVET institution's specific responses to IR 4.0 in any of the followings: a) strategy and leadership, (b) people (management and employees), (c) process of curriculum development and teaching-learning and assessment experience, and (d) technology (facilities and infrastructure) in response to IR 4.0
3. To gauge TVET representatives' expectations toward IR 4.0. implementation, such as on teaching-learning and assessment process, skills needed by their graduates, and roles of their graduates when they enter employment.

1.5 Data Analysis

The data collected from the survey questionnaire underwent analysis using descriptive statistics, including frequency distributions, means, and standard deviations. Given that the unit of analysis is institutional, instances where institutions provided multiple responses were consolidated into a single averaged response for each institution. This consolidation process ensures that each institution is represented by a comprehensive and averaged view of its responses. The responsibility for conducting data analysis rests with the country researchers, who applied these statistical methods to derive insights from the survey data. This approach ensures that the analysis is contextually grounded and aligns with the specific characteristics and needs of the institutions within their respective countries.

1.6 Respondents

The data presented in Table 1 provides a detailed overview of the survey and FGDs or interview participation from various TVET institutions and industry players across nine SEAMEO member countries.

In Brunei, the survey encompassed six TVET institutions. For the FGD session, 24 participants were involved, including 12 representatives from Higher and Technical Education Institutions and 12 industry players. The survey in Cambodia included seven TVET institutions. The FGD/ interview involved 12 participants, which comprised representatives from 10 TVET institutions and two industry players. Indonesia's participation was extensive, with surveys conducted across 153 institutions, encompassing of 124 Public Vocational High Schools (VHS), 14 polytechnic institutions, 12 university institutions, and three training institutions. For the FGD/ interview, participants included representatives from eight TVET institutions, seven industry players, and five members from industrial and business associations.

In Lao PDR, the survey included 25 TVET institutions. The FGD/ interview involved nine participants, including representatives from six TVET institutions and three industry players, ensuring a balanced view from both educational and industrial

stakeholders. Malaysia's survey involved six TVET institutions. The FGD/ interview included nine participants, with representatives from five TVET institutions and four industry players. The Philippines survey covered 62 institutions, including 41 TESDA Technology Institutions (TTIs) and 21 non-TTIs. For the FGD/interview, participants included representatives from one TTI and one non-TTI.

In Singapore, the survey included one TVET (represented by 332 staff members) and three polytechnic institutions. The FGD/ interview involved 22 participants, all from the management of the School of Engineering, Institute of Technical Education (ITE). Thailand's survey involved 20 TVET institutions. The FGD/ interview included nine participants, with representatives from five TVET institutions and four industry players. In Vietnam, the survey covered eight TVET institutions. The FGD/interview involved governing board members from seven institutions, ensuring a high-level perspective on the readiness and strategic planning for IR 4.0.

Overall, this comprehensive participation across various countries and institutions provides a robust dataset for evaluating the readiness of TVET institutions in Southeast Asia to embrace and implement Industry 4.0 technologies and processes. The inclusion of both educational and industry stakeholders in FGDs/ interviews ensures that the findings will be well-rounded and reflective of the actual needs and capabilities within each country.

Table 1. Institutions participating in the study.

Country	Survey	FGD/ Interview
Brunei	6 TVET institutions	12 HEIs & 12 Industry players
Cambodia	7 TVET institutions	10 TVET institutions & 2 Industry players
Indonesia	124 Public VHS institutions, 14 polytechnic institutions, 12 university institutions & 3 training institutions	8 TVET institutions, 7 Industry players & 5 Industrial & Business Association's representatives
Lao PDR	25 TVET institutions	6 TVET institutions & 3 Industry players

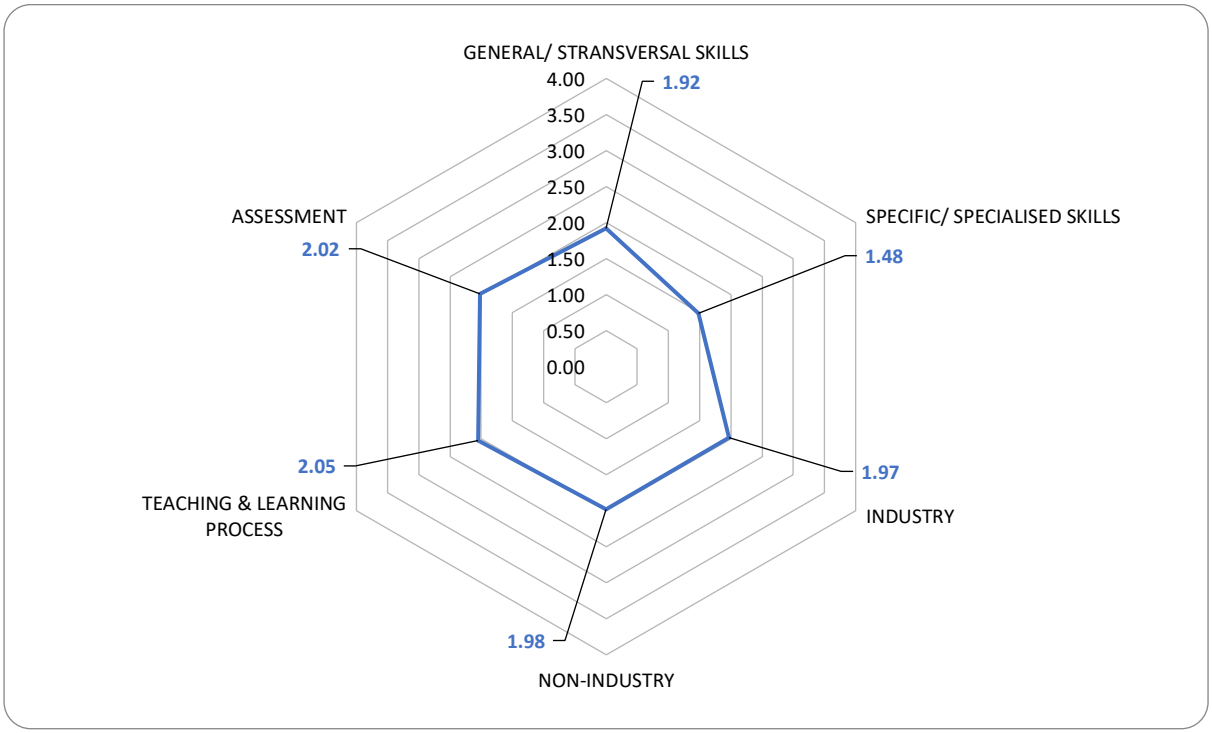
Malaysia	6 TVET institutions	5 TVET institutions & 4 Industry players
Philippines	41 TESDA Technology Institutions (TTIs) and 21 Non-TTIs	1 TTI and 1 Non-TTI
Singapore	1 TVET and 3 polytechnic institutions	22 Management from School of Engineering, ITE
Thailand	20 TVET institutions	5 TVET institutions & 4 Industry players
Vietnam	8 TVET institutions	Governing board members of 7 institutions

2.0 Findings

2.1 Process Block

The Process block comprises three key pillars: Curriculum, Stakeholders engagement, and Teaching and Learning. The regional readiness index for TVET institutions within the Process block has an average of 1.90, ranges from 1.37 to 2.47. The subsequent sections will provide a detailed discussion of the pillars and dimensions within the Process block.

Figure 2. The Readiness of TVET Institutions for IR 4.0 in six dimensions under Process block (1.90).



2.1.1 Curriculum Pillar

The Curriculum pillar emphasises the development and alignment of curriculum content in line with IR 4.0. The overall index of this pillar is 1.70 (range: 0.86 to 2.38). There are two dimensions in this pillar: (1) general/ transversal skills and (2) specific/ specialised skills. Shown in Table 2 and 3 are the assessment matrix of general/ transversal skills and specific/ specialised skills that consists of band, definition and

description. The band ranges from 0 (conventional) to 4 (exemplary) - this indicates the stages of IR 4.0 integration in the curriculum, starting from the use of existing curriculum (without IR 4.0) to the transformative use of IR 4.0 curriculum.

The general/ transversal skills are those typically considered as not specifically related to a particular job, task, academic discipline or area of knowledge but as skills that can be used in a wide variety of situations and work settings (IBE, 2013). The general/ transversal skills are complex problem solving, social skills, process skills, cognitive abilities, people management skills, content skills, digital skills and entrepreneurial skills. For general/ transversal skills, the participating TVET institutions in the nine SEAMEO member countries are at an early adopter stage (Brunei, Cambodia, Indonesia, Lao PDR and Philippines) and learner stage (Malaysia, Singapore, Thailand and Vietnam). The index of TVET institutions' readiness ranges from 1.28 to 2.81 and the overall readiness index for this dimension is 1.92.

Table 2. Assessment matrix of General/ Transversal skills.

PILLAR - CURRICULUM DIMENSION – GENERAL/ TRANSVERSAL SKILLS			
Band		**Definition**	**Description**
0	Conventional	Use existing curriculum	Curriculum content without IR 4.0
1	Early adopter	Early stage adopting IR 4.0 Curriculum	Curriculum content has a few components of IR 4.0
2	Learner	Moderate usage with IR 4.0 Curriculum	Curriculum content adopts basic components of IR 4.0
3	Experienced	Almost every time expose/ use IR 4.0 Curriculum	Curriculum content incorporates a majority of components of IR 4.0 in the context related to the area of specialisation
4	Exemplary	Transformative use of IR 4.0 Curriculum	Curriculum content incorporates all components of IR 4.0 in the context related to the area of specialisation and the Referral Centre of IR 4.0 curriculum

The second dimension, specific/ specialised skills include the specific “know-how” needed for a fulfilling and meaningful life and decent employment which learners

acquire often as a result of their participation in post-basic education, including through TVET or after-school activities. These skills may relate to a specific job, task, academic discipline (e.g., teacher, geographer, medical doctor or journalist) or area of particular knowledge and skills (e.g., hobby) (UNESCO Bangkok, 2014). The specific/ specialised skills include big data, autonomous robotics, simulations (Eg: augmented reality/ virtual reality), Artificial Intelligence (AI) and machine learning, Internet of Things (IoT), cloud computing, cyber security, smart manufacturing and block chain. The index range for this dimension spans from 0.44 to 2.18, with the overall index being 1.48. One of the countries involved has its TVET institutions classified as being in the conventional stage. In contrast, the remaining countries have their TVET institutions categorised as either in the early adopter stage or learner stage.

Table 3. Assessment matrix of Specific/ Specialised skills.

PILLAR - CURRICULUM DIMENSION – SPECIFIC/ SPECIALISED SKILLS			
Band		**Definition**	**Description**
0	Conventional	Use existing curriculum	Curriculum content without IR 4.0
1	Early adopter	Early stage adopting IR 4.0 Curriculum	Curriculum content only has a few components of IR 4.0
2	Learner	Moderate usage with IR 4.0 Curriculum	Curriculum content adopts basic components of IR 4.0
3	Experienced	Almost every time exposed to/use IR 4.0 Curriculum	Curriculum content incorporates a majority of components of IR 4.0
4	Exemplary	Transformative use of IR 4.0 Curriculum	Curriculum content incorporates all components of IR 4.0 and the Referral Centre of IR 4.0 curriculum

2.1.2 Stakeholders engagement pillar

The stakeholders' engagement pillar evaluates the involvement of TVET institutions with other individuals or institutions in the process of embedding and promoting components of IR 4.0 in the TVET system. The overall index of this pillar is 1.97 (range from 1.29 to 2.55). This pillar consists of industry and non-industry dimensions. Table

4 displays the assessment matrix of both dimensions with the band ranging from the lowest at 0 (no engagement) to the highest at 4 (innovative engagement).

The first dimension is to evaluate the engagement of TVET institutions with industry in the following areas: curriculum engagement, industrial attachment, staff training and development, skill-based assessment, funding, human resources, shared facilities, employment and apprenticeship of IR 4.0 related-technologies. The regional index of TVET institutions for this dimension is at 1.97 (range from 1.28 to 2.49). Majority of the TVET institutions are at passive compliance band (Brunei, Cambodia, Lao PDR and Philippines) and regulatory compliance band (Indonesia, Malaysia, Singapore, Thailand and Vietnam).

Meanwhile, the non-industry dimension entails to find the TVET institutions engagement with non-industry stakeholders such as parents, students, community, alumni, non-governmental organisations and government. Specifically, this dimension intends to evaluate the collaborative effort in these areas: curriculum alignment, service learning, industrial attachment, staff training and development, skill-based assessment, funding, human resources, shared facilities, employment, certification and research collaboration. The regional index for this dimension stands at 1.98 (with a range of 1.30 to 2.61), slightly surpassing the index for industry engagement. However, the bands achieved are comparable to those in industry engagement, predominantly falling within the passive compliance and regulatory compliance stages.

Table 4. Assessment matrix of Industry and Non-Industry Engagement.

PILLAR - STAKEHOLDERS ENGAGEMENT DIMENSION - INDUSTRY & NON-INDUSTRY			
Band		**Definition**	**Description**
0	No engagement	Zero engagement or involvement/no effort on IR 4.0	Stakeholders show no engagement effort towards the institutional tasks on IR 4.0
1	Passive compliance	Lack of effort and persistence engagement on IR 4.0	Stakeholders show minimal effort of engagement, lack of inquiry and interest towards the institutional tasks on IR 4.0

2	Regulatory compliance	Sufficient/moderate effort of engagement and involvement on IR 4.0	Stakeholders show sufficient engagement effort towards the institutional tasks on IR 4.0
3	Strategic compliance	Strategic, creative and productive effort of engagement and involvement on IR 4.0	Stakeholders show clear effort with some creativity and engaged focus on task directions to completion towards the institutional tasks/progress on IR 4.0
4	Innovative engagement	Concerted, continuous and innovative engagement and involvement on IR 4.0	Stakeholders show persistence towards a sustained inquiry that is proactive, self-engaged and directed with on-going interest and inquisitiveness, self-motivation for engagement and progress on IR 4.0

2.1.3 Teaching and Learning

For the teaching and learning pillar, the TVET institutions obtained a regional index of 2.03 (range: 1.63 to 2.74). There are two dimensions under this pillar: (1) teaching and learning process and (2) assessment.

The first dimension, teaching & learning process refers to combined processes where an instructor assesses learning needs, establishes specific learning objectives, develops teaching and learning strategies, implements plan of work and evaluates the outcomes of the instruction (Holz-Clause et al., 2015). This dimension evaluates the teaching and learning process in the TVET institutions based on the following: planning theoretical and practical lessons in classrooms/ workshops, planning theoretical and practical lessons in industrial workplaces, delivering learning sessions to support competence development of learners, involving students' competence development (in and out of lesson), improving learning and interaction processes by choosing and developing suitable methods and preparing learning and teaching materials and media. Table 5 displays the bands used for this dimension, starting with the conventional to transformational stage. Most of the countries are at adoption (Brunei, Cambodia, Indonesia, Lao PDR and Philippines) and adaptation stage (Malaysia, Singapore, Thailand and Vietnam). The overall index of TVET institutions for teaching and learning dimension is 2.05 (range: 1.49 to 2.67).

Table 5. Assessment matrix of teaching and learning process.

PILLAR - TEACHING & LEARNING DIMENSION - TEACHING & LEARNING PROCESS			
Band		**Definition**	**Description**
0	Conventional	Zero demonstration of the integration of IR 4.0 in teaching & learning process	– No evidence of IR 4.0 technology use in teaching & learning process – Instruction is teacher-centered (only lecture, with occasional demonstration and discussion, no tutorial) – Takes place fully in traditional classroom settings
1	Adoption	Demonstration of adoptive and directed use of IR 4.0 technology in teaching & learning process	– Instructor directs students on conventional and procedural use of IR 4.0 technology tools – Instruction is teacher-centered (heavily depending on lecture, with occasional use of demonstration, discussion and tutorial) – Takes place fully in traditional classroom settings
2	Adaptation	Demonstration of adaptive and independent (self-reliant) use of IR 4.0 technology in teaching & learning process	– Instructor facilitates the students' exploration and independent (self-reliant) use of IR 4.0 technology tools – Instruction is student-centered and self-paced learning (minimal use of lecture, frequent use demonstration, discussion and tutorial) – Takes place either in traditional classroom and/or blended learning settings
3	Infusion	Demonstration of infused and independent (self-reliant) use of IR 4.0 technology in teaching & learning process	– Instructor provides the learning context and the students choose the IR 4.0 technology tools – Instruction is student-centered and self-paced learning (occasionally use problem-based and project-based learning including minimal use of lecture, integration of demonstration, discussion and tutorial) – Takes place either in traditional classroom and/or blended learning settings
4	Transformati-onal	Demonstration of transformational and independent (self-reliant) IR 4.0 technology in teaching & learning process	– Instructor encourages the innovative use of IR 4.0 technology tools to facilitate higher order learning activities that may not be possible without the use of technology – Instruction is student-centred and self-paced learning (effective use of problem-based and or project-based learning with minimal use of lecture and selective use of demonstration, discussion and tutorial) – Takes place in a blended learning setting

The second dimension is assessment – which refers to the process of gathering evidence, making judgments, and drawing inferences about the achievement and performance of the students (Curtis, 2010). This dimension evaluates two key aspects: (1) the categories of assessments employed in teaching and learning, and (2) the kinds of digital tools utilised for assessment and feedback. The first facet aims to scrutinise the types of assessments integrated into teaching and learning, encompassing authentic assessment, constructivist assessment, and performance-based assessment. Simultaneously, the second aspect evaluates the incorporation of digital tools, including social media, simulations, learning management systems (LMS), gaming, and mobile apps, for conducting assessments and delivering feedback. Table 6 displays the bands used for this dimension, starting with the 0 (conventional) to 4 (transformational) stage. Most of the countries are at adoption (Brunei, Cambodia, Indonesia, Lao PDR and Philippines) and adaptation stage (Malaysia, Singapore, Thailand and Vietnam). The overall index of TVET institutions for teaching and learning dimension is 2.05 (range: 1.49 to 2.67).

Table 6. Assessment matrix of assessment.

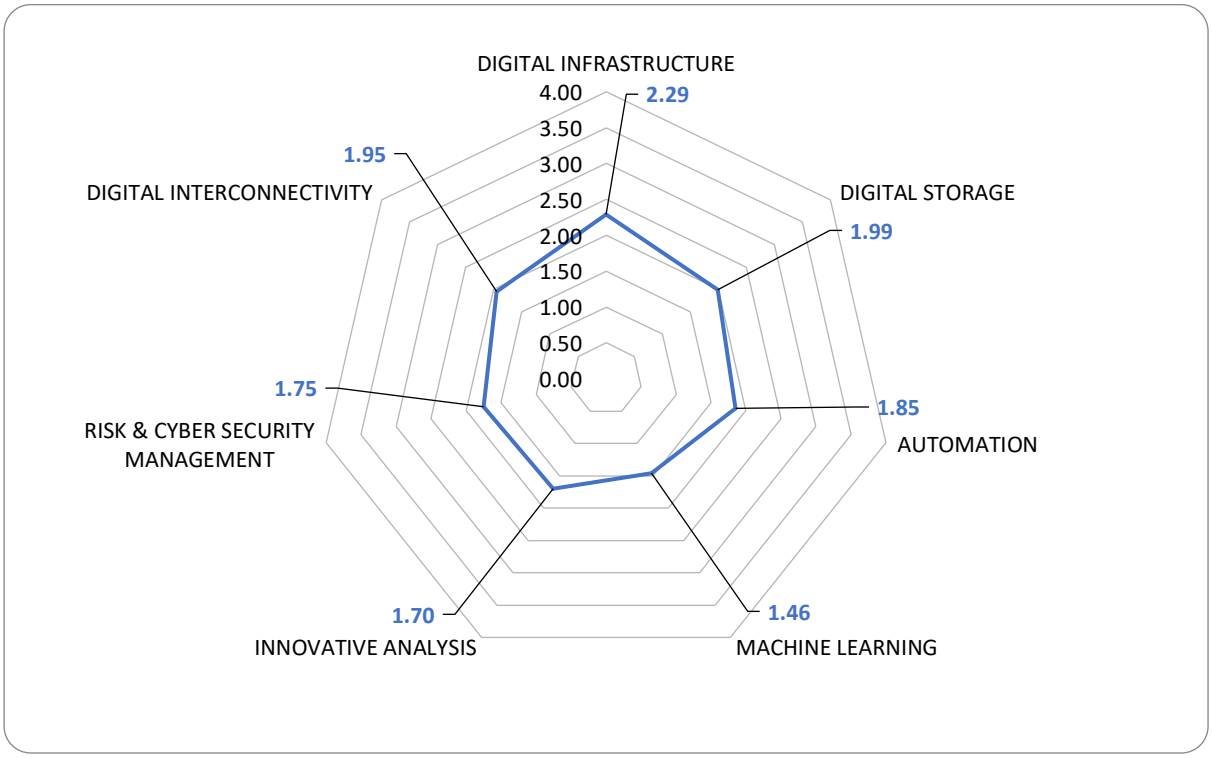
PILLAR - TEACHING & LEARNING DIMENSION - ASSESSMENT			
Band		**Definition**	**Description**
0	Conventional	Zero demonstration of IR 4.0 integration in assessment and feedback	– No evidence of IR 4.0 technology use in assessment and feedback – Contains a brief assessment by instructor via examination/test – Assessment conducted annually
1	Adoption	Demonstration of adoptive and directed use of IR 4.0 technology in assessment and feedback	– Instructor directs students in the procedural use of IR 4.0 technology tools in assessment and feedback – Contains a brief assessment by instructor mostly via examination/test and occasionally via practical – Assessment conducted annually
2	Adaptation	Demonstration of adaptive and independent use of IR 4.0 technology in assessment and feedback	– Instructor facilitates the students' exploration and independent use of IR 4.0 technology tools in assessment and feedback – Contains a comprehensive assessment by instructor with a mix of examination/test and practical – Assessment conducted twice a year

3	Infusion	Demonstration of infused and independent use of IR 4.0 technology in assessment and feedback	– Instructor provides the context of assessment, and the students choose the IR 4.0 technology tools – Contains a comprehensive assessment by instructor with a mix of examination/test and practical – Assessment conducted three times a year
4	Transformati-onal	Demonstration of transformational and independent IR 4.0 technology in assessment and feedback	– Instructor encourages the innovative use of IR 4.0 technology tools to facilitate assessment and feedback that may not be possible without the use of technology – Contains a comprehensive and innovative assessment by instructor with a mix of examination/test and practical – Assessment conducted continuously

2.2 Technology Block

The Technology block comprises three key pillars: Infrastructure, Intelligence and Connectivity. The regional. readiness index for TVET institutions within the Technology block is 1.89 (range from 1.14 to 3.05). The subsequent sections will provide a detailed discussion of the pillars and dimensions within the Technology block.

Figure 3. The Readiness of TVET Institutions for IR 4.0 in six dimensions under Technology block (1.89).



2.2.1 Infrastructure

The Infrastructure pillar emphasises the development and alignment of infrastructure content in line with IR 4.0. The overall index of this pillar is 2.14 (range: 1.28 to 3.16). There are two dimensions in this pillar: (1) digital infrastructure and (2) digital storage. Shown in Table 7 and 8 are the assessment matrix of digital infrastructure and digital storage consists of band, definition and description. The band ranges from 0 (conventional) to 4 (leader) - this indicates the stages of IR 4.0 integration in the

infrastructure, starting from the non-existence of digital infrastructure (without IR 4.0) to the existence of digital infrastructure and used extensively (IR 4.0 ready).

The first dimension is digital infrastructure readiness which refers to the preparedness of the institution to transition into digitised workflows that are enabled by software and technology. Digital infrastructure includes communication network infrastructure (E.g.: 5G, optical network, IoT) and computing power infrastructure (E.g.: intelligence, storage, computing, and data centers). It focuses on data and supports end-to-end data-related activities, including data collection, perception, real-time transmission and distribution, storage, computing, processing, mining, analysis, and decision-making (Huawei, 2015). The digital infrastructure readiness is hardware (e.g. internet backbone, data centers, network, network security), operating system (e.g. Apple Mac OS, Microsoft Windows, Google's Android OS, Linux Operating System); fast, safe and stable internet (e.g. 4G, 5G, optical network); learning management system and communication tools. For digital infrastructure readiness dimension in the nine SEAMEO member countries are at an early adopter stage and learner stage. The index of TVET institutions' readiness ranges from 1.45 to 3.52 and the overall index for this dimension is 2.29.

Table 7. Assessment matrix of Digital Infrastructural Readiness.

PILLAR - INFRASTRUCTURE DIMENSION - DIGITAL INFRASTRUCTURE READINESS			
Band		**Definition**	**Description**
0	Conventional	Non-existence of digital infrastructure	Institutions do not have any digital infrastructure in place
1	Early Adopter	Existence of digital infrastructure but not utilised due to lack of knowledge and understanding	Institutions have technology infrastructure but don't know how to utilise
2	Learner	Existence of digital infrastructure but not fully utilised	Institutions have the ability to use several types of technology
3	Experienced	Existence of digital infrastructure and used regularly and effectively	Institutions have the ability to choose and contextualise technological tools based on the institutional needs, thus able to flexibly utilise these tools

4	Leader	Existence of digital infrastructure and used extensively (IR4.0 ready)	Referral Centre of digital infrastructure and institutions effectively utilise the digital infrastructure according to its purpose

The second dimension; digital storage allows the users to store mass amounts of data in a small space, and allows the users to easily share information with others. The index range for this dimension spans from 1.10 to 3.04, with the overall index being 1.99. Two of the countries involved has its TVET institutions classified as being experienced stage in digital storage. While, the remaining countries have their TVET institutions categorised as either in the early adopter stage or learner stage.

Table 8. Assessment matrix of Digital Storage.

PILLAR - INFRASTRUCTURE DIMENSION - DIGITAL STORAGE			
Band		**Definition**	**Description**
0	Conventional	Non-existence of digital storage	Institutions do not have any digital storage in place
1	Early Adopter	Existence of digital storage	Institutions have basic digital storage such as hard drives and USB flash drives
2	Learner	Existence of digital storage but not effectively used	Institutions have the ability to use several types of digital storage, mostly utilise hard drives, USB flash drives and occasionally utilise cloud storage
3	Experienced	Existence of digital storage and used regularly	Institutions have the ability to choose, contextualise and integrate various technological usage such as hard drives, USB flash drives and cloud storage
4	Leader	Existence of digital storage and full automation (IR 4.0 ready)	Referral Centre of digital storage and institutions effectively utilises the technologies such as hard drives, USB flash drives, cloud storage and decentralised storage

2.2.2 Intelligence

The Intelligence pillar highlights the development and alignment of intelligence content in line with IR 4.0. The overall index of this pillar is 1.67 (range: 0.98 to 2.59). There are three dimensions in this pillar: (1) automation; (2) machine learning and (3)

innovative analysis. Shown in Table 9, 10 and 11 are the assessment matrix of automation, machine learning and innovative analysis which consists of band, definition and description. The band ranges from 0 (none) to 4 (full automation) for both automation and machine learning dimension – this indicates the stages of IR 4.0 integration in the intelligence, starting from the non-existence of automation technology to the existence of automation technology and full automation (IR 4.0 ready). Whereas the band ranges from 0 (none) to 4 (full integration) for innovative analysis dimension – this indicates the stages of IR 4.0 integration in intelligence from 0 (none) to 4 (full integration).

The first dimension is on automation that refers to intelligent automated technology that effectively connects users, systems, and data, that minimises the need for human interaction. The automation consists of intelligent automation technology (in administrative and/ or classroom); connect users online; systems and data (e.g., automated administrative workflows) and reduce human interventions. For automation dimension, the participating TVET institutions in the nine SEAMEO member states are at a visible and operation stage. The index of TVET institutions readiness ranges from 0.90 to 2.95 and the overall readiness index for this dimension is 1.85.

Table 9. Assessment matrix of Automation.

PILLAR - INTELLIGENCE **DIMENSION - *AUTOMATION***			
Band		**Definition**	**Description**
0	None	Non-existence of automation technology	Institutions do not have any automation technology in place
1	Visible	Existence of automation technology but not implemented	Institutions have automation technology but don't know how to utilise due to lack of knowledge and understanding
2	Operation Technology	Existence of automation technology but not effectively used	Institutions have the ability to use several types of automation technology
3	Semi-automation	Existence of automation technology and used regularly	Institutions have the ability to choose and contextualise technological tools based on the institutional needs, thus able to flexibly utilise automation technology

4	Full automation	Existence of automation technology and full automation (IR 4.0 ready)	Referral Centre of automation technology and institutions effectively utilises the technology according to its purpose

The second dimension highlights on machine learning which is a branch of artificial intelligence and computer science which focuses on the use of data and algorithms to imitate the way that humans learn, gradually improving its accuracy (IBM, 2020). Some of the implementations of machine learning in education settings: predict students' performance, learning analytics, improve retention rate (Kucak, Juricic & Dambic, 2018). The machine learning are data (large amount of data to train and learn patterns); algorithms (used to process the data and make predictions or decisions); building model (used to make predictions or decisions based on new data); data visualisation (can be simple, such as a single value, or complex, such as image or text); evaluation (to determine how accurate they are at making predictions or decisions) and optimisation (involves adjusting the algorithm, adding or removing features, or changing the data used to train the model). For machine learning dimension, the participating TVET institutions in the nine SEAMEO member states are at a visible and operation automation technology stage. The index of TVET institutions readiness ranges from 0.42 to 2.44 and the overall index for this dimension is 1.46.

Table 10. Assessment matrix of Machine Learning.

PILLAR - INTELLIGENCE **DIMENSION - MACHINE LEARNING**			
Band		**Definition**	**Description**
0	None	Non-existence of machine learning technology	Institutions do not have any machine learning technology in place
1	Visible	Existence but not fully implemented	Institutions have machine learning technology but don't know how to utilise due to lack of knowledge and understanding
2	Operation Technology	Existence but not effectively used	Institutions have the ability to use several types of machine learning technology
3	Semi-automation	Existence and used regularly	Institutions have the ability to choose and contextualise technological tools based on the institutional needs, thus able to flexibly utilise machine learning technology

4	Full automation	Existence and IR4.0 ready	Referral Centre of machine learning technology and institutions effectively utilise the technology according to its purpose

The third dimension is innovative analysis which refers to the technological advancement tools utilised by the institutions to carry out their day-to-day activities. The innovative analysis consists of analysis of students' learning abilities and performance; digital readers and tablets; augmented reality/ virtual reality, gamification; cloud technology and mobile technology. For the dimension of innovative analysis, the participating TVET institutions in the nine SEAMEO member states found few of the countries are at a none stage while the others are at a visible and operation automation technology stage. The index of TVET institutions readiness ranges from 0.90 to 2.70 and the overall index for this dimension is 1.70.

Table 11. Assessment matrix of Innovative Analysis.

PILLAR - INTELLIGENCE DIMENSION - INNOVATIVE ANALYSIS			
Band		**Definition**	**Description**
0	None	Non-existence of Innovative analysis	The institutions do not carry out innovative analysis
1	Visible	Existence but not implemented due to lack of knowledge and understanding	The institutions carry out innovative analysis but do not support the institutional strategies
2	Operation Technology	Existence but not effectively used	The institutions carry out innovative analysis as one of the problem-solving strategies in several fields
3	Semi-integration	Existence and used regularly	The institutions carry out innovative analysis as one of the problem-solving strategies as needed
4	Full integration	Existence and IR 4.0 ready	The institutions carry out innovative analysis in all fields

2.2.3 Connectivity

The Connectivity pillar emphasises the development and alignment of connectivity content in line with IR 4.0. The overall index of this pillar is 1.85 (range: 1.04 to 3.40). There are two dimensions in this pillar: (1) risk and cyber security and (2) digital connectivity. Shown in Table 12 and 13 are the assessment matrix of risk and cyber security and digital connectivity that consists of band, definition and description. The band ranges from 0 (none) to 4 (real-time and scalable) - this indicates the stages of IR 4.0 integration in the connectivity, starting from the systems are not connected to the inter-operable systems are secure and capable of real time communication and scalable.

Risk & cyber security management is the first dimension that practice of prioritising cybersecurity defensive measures based on the potential adverse impact of the threats they're designed to address (Chickowski, 2020). For the risk and cyber security management dimension, the participating TVET institutions in the nine SEAMEO member countries revealed to have none on risk and cyber security management while the others have either connected, inter-operable and secure connectivity. The index of TVET institutions readiness ranges from 1.04 to 3.20, and the overall readiness index for this dimension is 1.75.

Table 12. Assessment matrix of Risk and Cyber Security Management.

PILLAR - CONNECTIVITY DIMENSION - RISK & CYBER SECURITY MANAGEMENT			
Band		**Definition**	**Description**
0	None	Systems are not connected	Systems at the institutions are not able to interact or exchange information. Incompatibility between protocols, components, products, and system.
1	Connected	Systems are connected but not secure via multiple communication technologies and protocols	Institutions have formal network links that will enable equipment, machinery and computer-based systems to interact or exchange information. Institutions do not anticipate enterprise system vulnerabilities and machine level operational vulnerabilities that could be a security threat.
2	Inter-operable	Systems are inter-operable and exchangeable across	Equipment and computer-based systems at the institutions are able to interact and exchange information without significant restrictions.

		multiple communication technologies and protocols	
3	Inter-operable & secure	Inter-operable systems are secure	There is a vigilant and resilient security framework at the institutions to protect the network of inter-operable equipment and computer-based systems from undesired access and/or disruption.
4	Real-time and scalable	Inter-operable systems are secure and capable of real time communication and scalable	Institutions have a scalable, secure, and inter-operable platform which is IR 4.0 ready

Digital inter-connectivity is the second dimension which refers to the interaction between computers, servers/hub and the web that is fast and safe. For this second dimension, the participating TVET institutions in the nine SEAMEO member countries are found to have none digital inter-connectivity and similarly others possessed either connected and inter-operable and secure connectivity. The index of TVET institutions readiness ranges from 1.04 to 3.60, and the overall readiness index for this dimension is 1.95.

Table 13. Assessment matrix of Digital Inter-Connectivity.

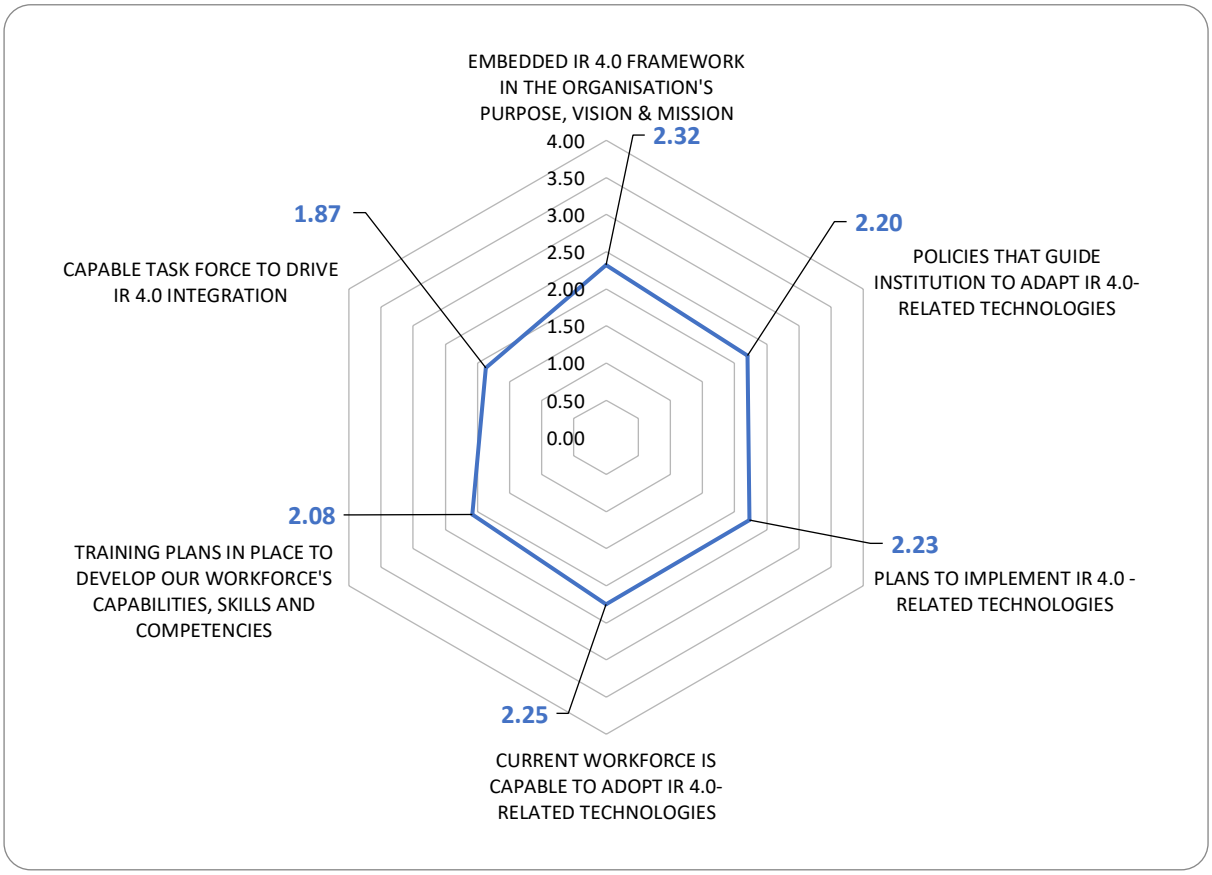
PILLAR - CONNECTIVITY **DIMENSION - DIGITAL INTER-CONNECTIVITY**			
Band		**Definition**	**Description**
0	None	Non-existence of any digital inter-connectivity	Institutions have zero digital ecosystem density (less than 50% using 4G)
1	Connected	Existence but not implemented due to lack of knowledge and understanding	Institutions have a huge gap in technical skills and knowledge on how to provide effective digital inter-connectivity (at least 50% using 4G)
2	Inter-operable	Existence but limited digital inter-connectivity	Institutions only have limited digital inter-connectivity as they need to redesign the current organisation and operational structures to be IR 4.0 ready (at least 75% using 4G)
3	Inter-operable & secure	Existence and used regularly	Institutions are digitally inter-connected but are not 100% IR 4.0 ready (100% using 4G)
4	Real-time and scalable	Existence and IR 4.0 ready	Institutions are 100% IR 4.0 ready with digital connectivity (wired or wireless) and possess full augmentation of machines with at least 5G* capabilities which provide faster response times,

			allowing for near real time communication between systems

2.3 Organisation Block

The Organisation block comprises two key pillars: Structure and Management and Talent Readiness. The readiness index for TVET institutions within the Organisation block ranges from 1.79 to 2.92, with an average of 2.16. The subsequent sections will provide a detailed discussion of the pillars and dimensions within the Organisation block.

Figure 4. The Readiness of TVET Institutions for IR 4.0 in six dimensions under Organisation block (2.16).



2.3.1 Structure and Management

The Structure and Management pillar highlights the development and alignment of structure and management content in line with IR 4.0. The overall index of this pillar is 2.25 (range: 1.75 to 2.93). There are three dimensions in this pillar: (1) IR 4.0 in vision and mission; (2) policies to adopt IR 4.0; and (3) plan to implement IR 4.0. Shown in Table 14, 15 and 16 are the assessment matrix of IR 4.0 in vision and mission, policies to adopt IR 4.0 and plan to implement IR 4.0 which consists of band, definition and description. These had different band ranges for the three dimensions. The band ranges from 0 (not stated at all) to 4 (strong influence) for the dimension on embedded IR 4.0 framework in the organisation's purpose, vision and mission. The band ranges from 0 (no policies) to 4 (extremely clear) for dimension on policies that guide institution to adapt IR 4.0 related technologies. Lastly, the band ranges from 0 (no plan) to 4 (extremely clear) for the dimension of plan to implement IR 4.0.

For the first dimension concerned on The IR 4.0 in vision and mission focused on whether the TVET institutions embedded IR 4.0 framework in the organisation's purpose, vision and mission. For this, the participating TVET institutions in the nine SEAMEO member countries are rather to not stated at all for some countries while the other countries are found to be on not clear as well as slight influence stage in terms of their organisations' vision and mission. The index of TVET institutions' readiness index ranges from 1.55 to 3.06 and the overall readiness index for this dimension is 2.32.

Table 14. Assessment matrix of Embedded IR4.0 in the organisation's purpose, vision & mission.

PILLAR - STRUCTURE & MANAGEMENT DIMENSION - EMBEDDED IR 4.0 FRAMEWORK IN THE ORGANISATION'S PURPOSE, VISION & MISSION		
Band		**Definition & Description**
0	Not stated at all	IR 4.0 is not mentioned in the purpose, vision and mission statements
1	Not clear	IR 4.0 is not stated clearly in the purpose, vision and mission statements

2	Slight influence	IR 4.0 is stated in the purpose, vision and mission statements and provided slight inspiration at some degree
3	Moderate influence	IR 4.0 is stated in the purpose, vision and mission statements and provided moderate inspiration
4	Strong influence	IR 4.0 is clearly articulated in the purpose, vision and mission statements and provided strong inspiration

Second dimension is on the policies to adopt IR 4.0 have policies that guide institution to adapt IR 4.0-related technologies. For this, the participating TVET institutions in the nine SEAMEO member countries are not clear, slightly clear and moderately clear stage. The index of TVET institutions' readiness index ranges from 1.47 to 3.00 and the overall readiness index for this dimension is 2.20.

Table 15. Assessment matrix of policies that guide institution to adapt IR4.0-Related Technologies.

PILLAR - STRUCTURE & MANAGEMENT DIMENSION - POLICIES THAT GUIDE INSTITUTION TO ADAPT IR 4.0-RELATED TECHNOLOGIES		
Band		**Definition & Description**
0	No policies	There are no institutional policies on the adaptation of IR 4.0-related technologies
1	Not clear	Institutional policies related to IR 4.0 exist but do not offer guidelines for the adaptation of IR 4.0 technologies
2	Slightly clear	Institutional policies related to adaptation of IR 4.0 technologies are stated briefly and provided guidelines to some degree
3	Moderately clear	Institutional policies to implement the adaptation of IR 4.0 technologies are stated and provided modest guidelines
4	Extremely clear	Institutional policies to implement and evaluate the adaptation of IR 4.0 technologies are comprehensive and provided clear guidelines

The last dimension concerned on the plan to implement IR 4.0 related technologies. For this, the participating TVET institutions in the nine SEAMEO member countries, few of the countries found in terms of having a plan to implement IR 4.0 related technologies are somehow not clear, while the other countries are somewhat clear

and moderately clear stage. The index of TVET institutions' readiness index ranges from 1.83 to 3.10 and the overall readiness index for this dimension is 2.23.

Table 16. Assessment matrix of plans to implement IR 4.0 Related technologies.

PILLAR - STRUCTURE & MANAGEMENT DIMENSION - PLANS TO IMPLEMENT IR 4.0 RELATED TECHNOLOGIES		
Band		**Definition & Description**
0	No plan	Institutions have no plan to implement IR 4.0-related technologies
1	Not clear	Plans to implement IR 4.0-related technologies exist but not stated clearly
2	Somewhat clear	Strategic plans to implement IR 4.0-related technologies exist and stated
3	Moderately clear	Strategic plans to implement and manage IR 4.0-related technologies exist and offer modest direction
4	Extremely clear	Strategic plans to implement, manage and evaluate IR 4.0-related technologies exist and offer clear direction

2.3.2 Talent Readiness

The Talent Readiness pillar highlights the development and alignment of structure and management content in line with IR 4.0. The overall index of this pillar is 2.07 (range: 1.64 to 2.92). There are three dimensions in this pillar: (1) workforce capability; (2) training plans; and (3) taskforce to drive IR 4.0. Shown in Table 17, 18 and 19 are the assessment matrix of IR 4.0 in workforce capability, training plans and taskforce to drive IR 4.0 which consists of band, definition and description. These had different band ranges for the three dimensions. The band ranges from 0 (not capable) to 4 (extremely capable) of the capability of current workforce in adopting IR 4.0-related technologies. The band ranges from 0 (no plan) to 4 (very effective) for training plans in place to develop the workforce's skills, abilities and personal qualities. Lastly, the band ranges from 0 (no task force assigned) to 4 (extremely capable taskforce) for the capability of taskforce to drive IR 4.0 integration.

Firstly, dimension on the workforce capability for current workforce in adopting IR 4.0-related technologies were highlighted. For this, the participating TVET institutions in

the nine SEAMEO member countries found to have of which few countries are rather slightly capable stage in having a capable workforce for current workforce in adopting IR 4.0-related technologies, and the other countries shown to be on somewhat capable and moderately capable stage. The index of TVET institutions' readiness index ranges from 1.75 to 2.83 and the overall readiness index for this dimension is 2.25.

Table 17. Assessment matrix of current workforce capability of adopting IR 4.0 Related technologies.

PILLAR - TALENT READINESS DIMENSION - CURRENT WORKFORCE IS CAPABLE OF ADOPTING IR 4.0-RELATED TECHNOLOGIES		
Band		**Definition & Description**
0	Not capable	The current workforce is unable to demonstrate adequate skills, abilities and personal qualities to carry out tasks related to IR 4.0 technologies
1	Slightly capable	The current workforce possesses limited skills, abilities and personal qualities relevant to carry out tasks related to IR 4.0 technologies
2	Somewhat capable	The current workforce possesses some skills, abilities and personal qualities relevant to carry out tasks related to IR 4.0 technologies
3	Moderately capable	The current workforce possesses modest skills, abilities and personal qualities and is moderately able to carry out tasks related to IR 4.0 technologies
4	Extremely capable	The current workforce possesses extensive skills, abilities and personal qualities and is highly capable to carry out tasks related to IR 4.0 technologies

Secondly, the training plans in place to develop the workforce's skills, abilities and personal qualities. For this dimension, the participating TVET institutions in the nine SEAMEO member countries revealed some of the countries have inadequate stage in terms of training plans in place to develop the workforce's skills, abilities and personal qualities. The remaining countries are found to be in need of improvement and effective stage. The index of TVET institutions' readiness index ranges from 1.57 to 3.09 and the overall readiness index for this dimension is 2.08.

Table 18. Assessment matrix of training plans in place to develop the workforce's skills, abilities and personal qualities.

PILLAR - TALENT READINESS DIMENSION - TRAINING PLANS IN PLACE TO DEVELOP THE WORKFORCE'S SKILLS, ABILITIES AND PERSONAL QUALITIES		
Band		**Definition & Description**
0	No plan	No training plan for upskilling/reskilling/cross-skilling the workforce
1	Inadequate	Training plans are limited and offer insufficient guidelines for upskilling/ reskilling/cross-skilling the workforce
2	Needs improvement	Training plans offer guidelines but lack of clarity, relevancy and practicability to upskill/reskill/cross-skill the workforce
3	Effective	Training plans offer guidelines with modest clarity, relevancy and practicability to upskill/reskill/cross-skill the workforce
4	Very effective	Training plans offer guidelines with extensive clarity, relevancy and practicability to upskill/reskill/cross-skill the workforce

Lastly, a dimension on the taskforce to drive IR 4.0. This third dimension found some of the participating TVET institutions in the nine SEAMEO member countries have no capable taskforce assigned in place to drive IR 4.0. Whereas some of the countries have sufficiently capable taskforce as well as some countries have capable taskforce to drive IR 4.0. The index of TVET institutions' readiness index ranges from 1.06 to 3.13 and the overall readiness index for this dimension is 1.87.

Table 19. Assessment matrix of capable taskforce to drive IR 4.0 Integration.

PILLAR - TALENT READINESS DIMENSION - CAPABLE TASKFORCE TO DRIVE IR 4.0 INTEGRATION		
Band		**Definition & Description**
0	No taskforce assigned	No taskforce to drive IR 4.0 integration
1	No capable taskforce	The taskforce is able to develop a timetable or short-term plan with limited execution
2	Sufficiently capable taskforce	The taskforce is able to develop various ranges of plans with modest execution capability
3	Capable taskforce	The taskforce is able to develop various ranges of plans and capable of driving IR 4.0 integration in the organisation with minimal stakeholders' engagement

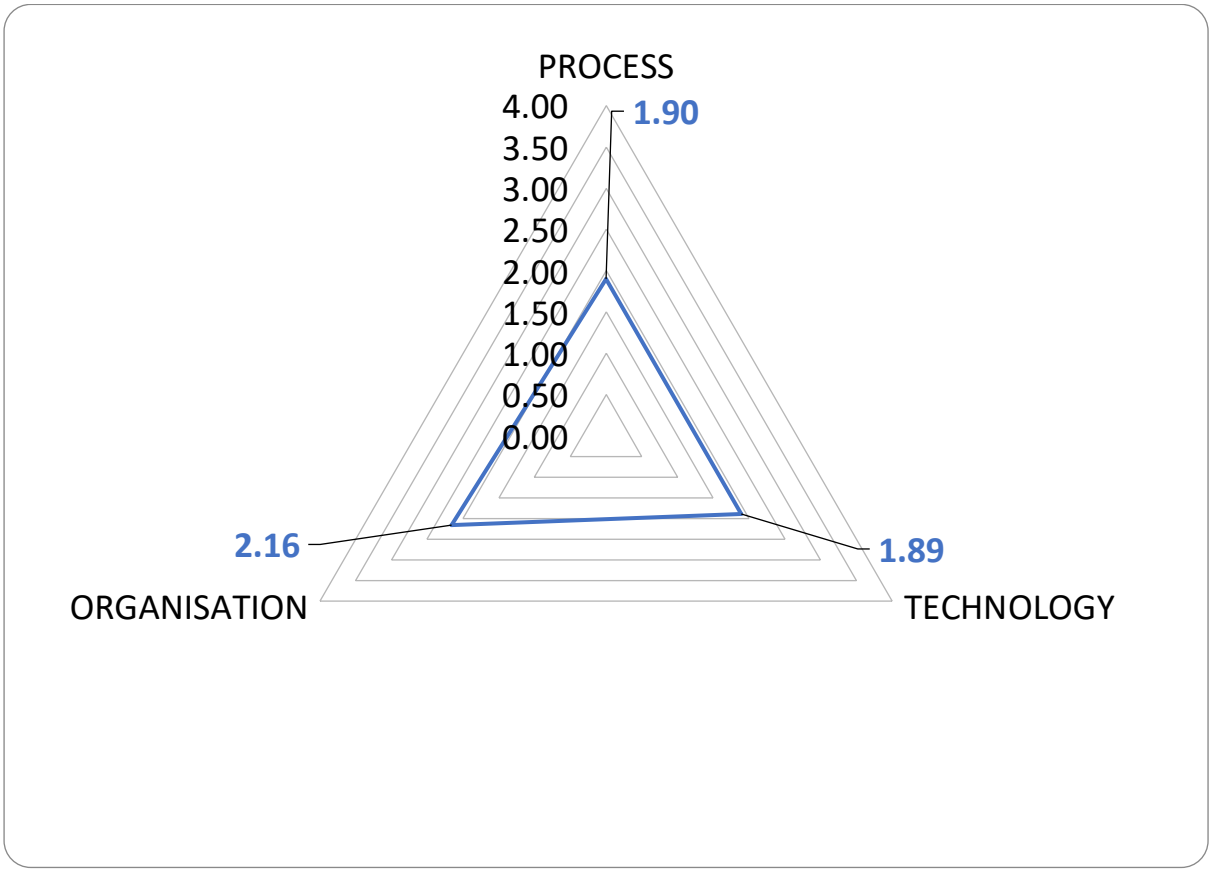
4	Extremely capable taskforce	The taskforce is able to develop various ranges of plans and capable of driving IR 4.0 integration in the organisation with full stakeholders' engagement

2.4 Overall Findings

Table 20. Overall Smart Education Readiness Index (SERI) of the three building blocks.

<table>
<tr><th colspan="8">PROCESS</th></tr>
<tr><th colspan="2">Curriculum</th><th colspan="2">Stakeholders engagement</th><th colspan="4">Teaching & Learning</th></tr>
<tr><td>General/ Tranversal skills</td><td>Specific/ Specialised</td><td>Industry</td><td>Non-industry</td><td colspan="2">Teaching & Learning Process</td><td>Assessment</td></tr>
<tr><td>1.92</td><td>1.48</td><td>1.97</td><td>1.98</td><td colspan="2">2.05</td><td>2.02</td></tr>
<tr><td colspan="2">1.70</td><td colspan="2">1.97</td><td colspan="3">2.03</td></tr>
<tr><td colspan="8">1.90</td></tr>
<tr><th colspan="8">TECHNOLOGY</th></tr>
<tr><th colspan="2">Infrastructure</th><th colspan="3">Intelligence</th><th colspan="2">Connectivity</th></tr>
<tr><td>Digital Infrastructure readiness</td><td>Digital Storage</td><td>Automation</td><td>Machine Learning</td><td>Innovative Analysis</td><td>Risk & Cyber security</td><td>Digital inter-connectivity</td></tr>
<tr><td>2.29</td><td>1.99</td><td>1.85</td><td>1.46</td><td>1.70</td><td>1.5</td><td>1.95</td></tr>
<tr><td colspan="2">2.14</td><td colspan="3">1.67</td><td colspan="2">1.85</td></tr>
<tr><td colspan="8">1.89</td></tr>
<tr><th colspan="8">ORGANISATION</th></tr>
<tr><th colspan="3">Structure & Management</th><th colspan="5">Talent Readiness</th></tr>
<tr><td>Embedded IR 4.0 framework organisation's Purpose, Vision & Mission</td><td>Policies that guide institution to adapt IR 4.0-related technologies</td><td>Plans to implement IR 4.0-related technologies</td><td>Current workforce is capable to adopt IR 4.0-related technologies</td><td colspan="2">Training Plans in place to develop our workforce's capabilities, skills and competencies</td><td>Capable taskforce to drive IR 4.0 integration</td></tr>
<tr><td>2.32</td><td>2.20</td><td>2.23</td><td>2.25</td><td colspan="2">2.08</td><td>1.87</td></tr>
<tr><td colspan="3">2.25</td><td colspan="5">2.07</td></tr>
<tr><td colspan="8">2.16</td></tr>
</table>

Figure 5. Overall Smart Education Readiness Index (SERI) of the three building blocks (1.98).



2.5 FGD Findings

2.5.1 TVET Institutions

The qualitative findings obtained from the interview and FGD sessions with representatives from TVET institutions and industry stakeholders have been analysed to identify the common themes that emerged. This analysis allows for a comprehensive understanding of the perspectives and insights shared by the participants, highlighting critical areas of focus and concern related to the integration of IR 4.0 within TVET institutions. By categorising and examining the data through these recurring themes, the analysis provides a structured framework to address the multifaceted challenges and opportunities associated with the adoption of IR 4.0 technologies and methodologies in the educational sector. This approach not only

facilitates the identification of overarching trends and patterns but also underscores the specific needs and priorities of both TVET institutions and industry representatives. The emergent themes from the FGD sessions with the TVET institutions encompass a wide range of issues, including the importance of integrating IR 4.0 in TVET institutions, policy development and implementation, resource and infrastructure needs, innovation and skills development, alignment with industry needs, gender inequality and inclusivity, partnership and collaboration and continuous evaluation and adaptation.

Figure 6. Common themes from the FGD sessions with TVET representatives.

2.5.1.1 Importance of integrating IR 4.0 in TVET institutions

The first emerging theme highlights the vital role TVET institutions in preparing graduates for future employment opportunities by integrating IR 4.0 components into their vision and mission statements. Apart from this, institutions recognised the transformative impact of IR 4.0 on graduate employability and socio-economic growth. Hence, institutions must ensure that their educational programmes are aligned with the demands of the rapidly evolving job market.

In Brunei, the responses regarding the presence of IR 4.0 in TVET institutions varied significantly, reflecting different perspectives on what IR 4.0 entails. Some participants associated IR 4.0 with the use of technologies like Virtual Reality (VR) and ChatGPT as teaching aids, while others focused on integrating components like automation, the Internet of Things (IoT), smart technologies, and blockchain technology into the curriculum. This variation indicates differing levels of adoption and implementation of

IR 4.0, either as a tool for teaching and learning or as a core component of the curriculum.

In Cambodia, participants demonstrated a keen interest in TVET readiness for IR 4.0. For instance, a participant emphasised their commitment to upgrading knowledge in areas such as Artificial Intelligence (AI) and automation. The participant highlighted the recent advancements in technology at their institute, such as the adoption of automatic machines controlled by codes, supported by the Asian Development Bank. This progress showcases the institution's proactive steps towards integrating IR 4.0, aligning with the broader theme of preparing graduates for future employment and socio-economic growth by embedding advanced technological components in their educational programmes.

Indonesia's TVET institutions have already incorporated IR 4.0 into their vision and mission, acknowledging the need to adapt to this industrial revolution. Participants noted the significant impact of IR 4.0 on user needs, emphasising the necessity for educators and students to optimally utilise the latest technologies. The institutions have implemented cloud systems and web-based e-attendance for academic and financial operations, and they plan to expand these technologies to other areas. Despite these advancements, there is a recognition of the need for further improvements to build a robust and systematic database. This aligns with the broader objective of ensuring that educational programmes meet the demands of the evolving job market and enhance graduate employability.

In Malaysia, participants agreed on the necessity of readiness and acceptance of IR 4.0 modifications in TVET institutions. There is a focused effort on improving students' computer literacy and access to internet facilities, recognising that these are crucial for students' readiness to enter the industry. The availability of computer equipment and enhanced computer literacy among students is seen as a vital step towards aligning educational programmes with the needs of the job market and ensuring that graduates are well-prepared for future employment opportunities. This reflects the institutions' commitment to embedding IR 4.0 components into their vision and mission statements, emphasisng their role in socio-economic growth.

The discussions across Brunei, Cambodia, Indonesia, and Malaysia highlight a common understanding of the importance of integrating IR 4.0 in TVET institutions. While the approaches and levels of implementation vary, the overarching goal remains the same: to prepare graduates for future employment opportunities and contribute to socio-economic growth by aligning educational programmes with the demands of the rapidly evolving job market. The insights from each country underscore the vital role of TVET institutions in this transformation and the necessity of embedding IR 4.0 components into their vision and mission statements.

2.5.1.2 Policy development and implementation

The second theme is emphasising the development and implementation of specific policies tailored to the integration of IR 4.0 technologies to ensure the effective adoption of these innovations in TVET institutions. In Lao PDR, there is a mixed response regarding the formation of task forces for digital transformation and change. Some institutions have already established committees to oversee digital transformation, indicating proactive steps towards policy development. For instance, a director noted, “Yes, my organisation has appointed a committee for digital transformation and change.” Conversely, other institutions have not yet initiated this process, highlighting the need for a more structured approach to policy development and implementation.

Meanwhile, Singapore’s approach to integrating IR 4.0 in TVET institutions is highly structured and strategic. The institutions have a clearly articulated vision statement that underscores their commitment to preparing students for the future workforce and embracing technological advancements. The strategic plan of the Institute of Technical Education (ITE) includes specific goals and initiatives related to IR 4.0. The alignment of ITE’s plans with the 23 National Industry Transformation Maps (ITM), introduced by various government agencies in 2016, demonstrates a comprehensive strategy to address the evolving needs of industries. This alignment ensures that programmes equip students with relevant skills, thereby contributing to economic growth and

developing a skilled workforce. The clear policy guidelines and strategic planning serve as a model for effective IR 4.0 implementation.

In Thailand, there is a recognised need for private TVET educational institutions to prepare for IR 4.0. The discussion highlighted the importance of educating those responsible for policy and practice on the need to provide clear policy guidelines for the operation of educational institutions. Additionally, there is a call for these stakeholders to disseminate more knowledge about IR 4.0 in a unified direction to ensure consistent implementation across institutions.

On the other hand, Vietnam faces challenges related among teachers in embracing IR 4.0 technologies. Despite the desire to adapt and evolve teaching practices, there is significant apprehension and hesitation due to fear of the unknown. One of the interviewees noted, “Teachers want to make changes, but implementing policies and taking action can be quite challenging.” This points to the necessity of developing supportive policies that address the specific needs and concerns of teachers to facilitate their adaptation to new technologies.

The FGDs across Lao PDR, Singapore, Thailand, and Vietnam reveal a varied landscape in the development and implementation of policies for integrating IR 4.0 technologies in TVET institutions. While Singapore demonstrates a well-structured and strategic approach, Lao PDR and Thailand are in the initial stages of forming task forces and educating stakeholders. Vietnam faces unique challenges with teacher adaptation, necessitating supportive policies and comprehensive training. Overall, the insights highlight the critical need for clear policy development and implementation guidelines to ensure the seamless integration of IR 4.0 technologies, thereby enhancing the effectiveness of TVET institutions in preparing students for future employment opportunities.

2.5.1.3 Resource and infrastructure needs

The third theme calls attention to address the resource and infrastructure needs for TVET institutions to effectively incorporate IR 4.0 technologies into their programmes.

Investments in skilled instructors, modern equipment, and updated facilities are essential to provide students with hands-on training opportunities and ensure their readiness for the digital workforce. Moreover, updating technology and infrastructure in training institutes demonstrates a commitment to preparing graduates for the demands of IR 4.0 industries.

Participants in Brunei highlighted challenges experienced during the transition to online learning and working, especially during the COVID-19 pandemic. These challenges spanned infrastructure, operational, and pedagogical aspects. Additionally, the participants emphasised the importance of management support in moving towards the integration of IR 4.0 in TVET institutions. Similarly, respondents from Cambodia's TVET institutions identified a significant need for resources, including skilled instructors, IR 4.0 equipment, and updated facilities. Participants noted that continuous development, monitoring, and careful planning are necessary to ensure successful integration of IR 4.0 technologies.

In Indonesia, TVET institutions have exhibited a proactive attitude towards IR 4.0, driven by good planning, flexibility, and mature strategies. The focus has been on proper training, upgrading technology, and enhancing learning facilities and infrastructure. However, some participants pointed out challenges related to financial constraints and government policies, which affect the provision of necessary infrastructure. Lao PDR's participating TVET institutions face discomfort with the integration of IR 4.0 due to outdated teaching equipment and the need for significant budget allocations for teacher development and equipment purchases. Some directors acknowledged the potential benefits of IR 4.0 but also highlighted the difficulties in keeping up with rapid technological changes.

Malaysia's TVET institutions face challenges in adapting to IR 4.0, particularly regarding cost and facilities. Participants reported insufficient ICT rooms and non-uniformity of equipment across vocational colleges, which complicates the development of standardised curricula and assessments. These infrastructure deficiencies hinder students' ability to complete assignments and develop competencies in line with industry standards. In Singapore, financial challenges create

a digital divide among students, with some having more access to digital devices than others. This gap impacts the overall effectiveness of IR 4.0 integration in TVET institutions. Addressing these financial challenges is crucial to ensure equal access to technology and learning opportunities for all students.

Participants from Thailand's TVET institutions state that need for significant funding, technology, and personnel support to manage and teach across all disciplines effectively. The rapid changes in industry demands outpace the institutions' ability to invest in modern equipment and machinery. Despite these challenges, there is a strong determination to develop infrastructure, knowledgeable personnel, and full readiness for IR 4.0. Participants from Vietnam's TVET institutions struggle with relatively low levels of infrastructure, IT capabilities, and learning materials. The FGDs revealed significant obstacles, including inadequate infrastructure and a shortage of human resources. These deficiencies make it difficult to implement and utilise advanced IR 4.0 technologies effectively. Participants emphasised the need for substantial investments in resources and expertise to overcome these challenges.

The FGDs underscore the critical need for investments in resources and infrastructure to integrate IR 4.0 technologies into TVET institutions. Addressing these needs involves enhancing the skills of instructors, updating technological equipment, and improving facilities to provide students with practical training opportunities. By committing to these investments, TVET institutions can better prepare graduates for the demands of IR 4.0 industries and ensure their readiness for the digital workforce.

2.5.1.4 Innovation and skills development

The fourth theme underscore the need for innovation in teaching methodologies and curriculum design for fostering creativity, critical thinking, and adaptability among students in the context of IR 4.0. Upskilling educators and promoting the development of innovative teaching methodologies are key strategies for enhancing students' readiness for the digital age.

In Brunei, participants recognised the critical need for teachers to be AI literate and understand AI capabilities in teaching and learning. Continuous professional development is necessary for educators to effectively use AI as a teaching tool or to teach AI subjects. Participants acknowledged that AI can be a supporting tool for teaching and learning, such as using ChatGPT, or can be integrated into multiple aspects of the curriculum.

Indonesia's TVET institutions view IR 4.0 as a significant opportunity to enhance learning and skill development. The integration of digitalisation and automation into teaching practices makes learning more engaging and fun for students. Institutions focus on upgrading learning methodologies, practical tools, and digital literacy for both students and educators. Despite challenges, such as the need for training older staff, the response from the workforce has been enthusiastic.

In Lao PDR, the Directors of TVET institutions noted varying levels of digital technology utilisation, with some institutions excelling in the use of online tools for instruction and administration. The discussions highlighted the need for modernised teaching equipment and the necessity for budget increases to develop teacher capabilities and update facilities.

Malaysia's TVET institutions have adopted the "adopt and adapt" principles for IR 4.0, transforming traditional methods into digital practices. The use of platforms like WhatsApp and Telegram for information delivery has improved communication and relationships among teachers, staff, and students. This adoption of technology reflects the institution's commitment to innovation. By utilising IR 4.0 technologies, these institutions enhance the learning experience and ensure that students are well-prepared for the digital workforce.

Singapore's TVET institutions focus on adapting to new technologies and innovative pedagogical approaches to ensure effective teaching and learning. Equitable access to educational opportunities is crucial in the face of technological advancements. The implementation of IR 4.0 involves creating virtual learning environments, incorporating multimedia activities, and providing real-time feedback. Professional development

programs under the Digital & Technology Roadmap (DTR) and the upcoming Future Skills Roadmap (FSR) are designed to equip teachers with the necessary skills to incorporate IR 4.0 concepts. These initiatives promote a technology-driven teaching-learning paradigm that fosters dynamic, interactive lessons and critical thinking skills among students.

In Thailand, developing teachers' expertise in new technologies and fostering cooperation with enterprises are vital for effective education management. Continuous development of the IR 4.0 curriculum in collaboration with enterprises and experts ensures that educational practices remain relevant and innovative. Emphasising human resources development in education supports the alignment with IR 4.0-compliant operations. This collaborative approach helps educators stay updated with industry advancements and integrate these into their teaching methodologies, thereby preparing students for the evolving job market.

The FGDs highlight the essential need for innovation in teaching methodologies and curriculum design to foster creativity, critical thinking, and adaptability among students. Upskilling educators and promoting innovative teaching practices are critical strategies for enhancing students' readiness for the digital age. By addressing these needs, TVET institutions can better prepare graduates for the demands of IR 4.0 industries and ensure their success in the digital workforce.

2.5.1.5 Alignment with industry needs

The fifth emerging theme accentuate the importance of strengthening partnerships with industry stakeholders for ensuring that TVET curriculum remains relevant to emerging industry demands. By aligning training programmes with industry needs and focusing on emerging technologies, institutions can enhance graduate employability and facilitate smooth transitions into the workforce.

In Indonesia, TVET institutions have made significant strides in ensuring that their curricula align with industry expectations. This alignment is achieved through periodic

synchronisation with industry partners, ensuring that the curriculum remains relevant and responsive to technological developments and job market needs. The proactive approach of regularly updating the curriculum helps institutions stay ahead of industry trends and prepares students for current and future job market demands. Indonesian TVET institutions conduct regular reviews and updates of their curricula in collaboration with industry stakeholders. This ongoing process ensures that the content taught to students is always up to date with the latest technological advancements and industry requirements.

In Singapore, the Institute of Technical Education (ITE) is at the forefront of adopting IR 4.0 technologies to revamp its curriculum. The incorporation of these technologies brings forth numerous opportunities for innovative and effective learning experiences, equipping students with the necessary skills to tackle future workforce challenges. The participants mentioned that ITE is actively updating its curriculum to ensure that students remain up to date with the latest industry developments. This revamp includes the integration of IR 4.0 technologies, which not only enhances learning experiences but also prepares students for new career opportunities in emerging fields. By incorporating technologies such as automation, artificial intelligence, and the Internet of Things (IoT), ITE is able to create more engaging and effective learning environments. The adoption of IR 4.0 technologies opens up new career pathways for students, aligning their education with the needs of future industries. This forward-thinking approach ensures that graduates are not only employable but also capable of thriving in a technologically advanced job market.

The discussions highlight the crucial role of industry partnerships in maintaining relevant and up-to-date TVET curricula. By periodically synchronising curricula with industry needs, Indonesian institutions ensure that their graduates are well-prepared for the job market. In Singapore, ITE's integration of IR 4.0 technologies into its curriculum exemplifies how adopting emerging technologies can create innovative learning experiences and open up new career opportunities for students. These efforts collectively enhance graduate employability and facilitate smooth transitions into the workforce, ultimately contributing to the development of a skilled and adaptable workforce ready to meet the demands of the digital age.

2.5.1.6 Gender inequality and inclusivity

Meanwhile, the sixth theme is surrounding the notion of addressing gender gaps and inequalities in access to IR 4.0 education and training opportunities is essential for promoting inclusivity and diversity in TVET institutions. The participants urged for collective efforts to prevent job displacement during the transition to IR 4.0 should prioritise bridging gender disparities and ensuring equal access to resources and support for all individuals.

In Singapore, schools have taken significant steps to ensure inclusivity and equal access to educational resources by making assistive technologies available for students with special educational needs (SEN). These technologies include screen readers, captioning, and text-to-speech software, which support students with physical or learning challenges. By providing these resources, Singaporean TVET institutions are working to ensure that all students, regardless of their abilities, have equal opportunities to benefit from education and training in the context of IR 4.0. The implementation of assistive technologies demonstrates a commitment to creating an inclusive learning environment where every student can thrive. This approach not only addresses the needs of students with SEN but also promotes broader inclusivity by ensuring that educational opportunities are accessible to all.

In Vietnam, the discussions brought to light the socio-economic implications of gender gaps and inequalities in the workforce. The country faces significant challenges due to a limited number of high-skilled workers and substantial gender disparities. These gaps pose a risk of job displacement during the transition to IR 4.0. The lack of high-skilled workers, coupled with gender inequalities, could hinder Vietnam's ability to fully leverage the opportunities presented by IR 4.0 technologies. Therefore, addressing these issues is crucial for fostering a balanced and inclusive economic growth that benefits all segments of society.

The collective efforts to address gender gaps and inequalities in TVET education and training highlight the importance of fostering an inclusive environment where all individuals can access the resources and support that they need to succeed. Ensuring equal access to IR 4.0 education and training opportunities is essential for promoting diversity, preventing job displacement, and preparing a skilled workforce that can meet the demands of the digital age.

2.5.1.7 Partnership and collaboration

The seventh theme highlights collaboration between TVET institutions, industry, and non-industry partners is essential for bridging skills gaps and improving funding support. By strengthening partnerships and aligning curriculum with industry demands, institutions can enhance graduate employability and facilitate their integration into the workforce. Additionally, staying updated on clients' needs and feedback channels can further enhance collaboration efforts and ensure the relevance of training programs.

In Brunei, participants highlighted the challenge of limited industry placements available for students to gain exposure to work practices involving AI applications. One participant noted, "We can produce students who have the ability to learn how to do this stuff, when they engage in industry. What we don't have is the industry for them to engage with. And the industry needs to be focused. We can't just do everything." This underscores the necessity of building targeted partnerships with industries that can provide relevant hands-on experience for students, ensuring that the curriculum is closely aligned with industry requirements and that students are well-prepared for the workforce.

In Lao PDR, the focus was on the importance of teacher training and exchanges with companies. One participant emphasised, "Training teachers and sending them to exchange with the company." This approach not only enhances the practical knowledge and skills of the teachers but also ensures that they are up to date with the latest industry practices and technologies. Such exchanges can significantly

contribute to the relevance of the training provided by TVET institutions, ensuring that students receive education that is aligned with current industry standards and expectations.

Singapore's ITE faces specific concerns with the advent of IR 4.0, such as the cost of implementing advanced technologies and the growing skills gaps due to rapid technological changes. Addressing these concerns requires proactive measures and collaboration among ITE leaders, industry partners, and policymakers to ensure vocational education remains relevant and effective. Collaboration and communication play a crucial role in this context, enabling students and teachers to connect and learn with individuals globally. By utilising communication and collaboration tools, IR 4.0 fosters opportunities for broadening perspectives and developing a more global outlook. ITE has established strong connections with industries through staff attachments, regular company visits, and other initiatives like the Industry Attachment/Industry Experience programs, Memorandum of Understanding/Letter of Collaboration agreements, and partnerships. These collaborations allow ITE to leverage the expertise and resources of industry partners, providing students with valuable opportunities for internships, work placements, and industry projects. This ensures that ITE's programs and initiatives remain relevant, practical, and aligned with industry expectations.

In the Philippines, a regional training centre utilizes virtual reality (VR) and augmented reality (AR) for its welding course, and mechatronics for manufacturing courses. Partnerships with major industry groups have granted access to state-of-the-art facilities for training purposes, such as cold storage and refrigeration for logistics-related courses. These collaborations enhance the learning experience by providing students with cutting-edge technology and resources, ensuring that they are well-equipped to meet the demands of the modern workforce.

The discussions from the FGDs underscore the vital role of partnerships and collaboration in TVET education. By aligning curricula with industry needs, providing practical training opportunities, and ensuring that educators are well-versed in the latest industry practices, TVET institutions can significantly enhance graduate

employability and facilitate their seamless integration into the workforce. Moreover, establishing strong feedback channels and staying updated on clients' needs will ensure that training programs remain relevant and effective in preparing students for the challenges of IR 4.0.

2.5.1.8 Continuous evaluation and adaptation

The last theme is continuous monitoring and evaluation of IR 4.0 implementation efforts are necessary to identify areas for improvement and make timely adjustments to training programs. By assessing and enhancing teaching and learning processes, institutions can ensure that graduates are equipped with the skills and knowledge needed to succeed in IR 4.0 industries.

In Singapore, the challenges posed by IR 4.0 in the education sector are multifaceted. Therefore, continuous learning and adaptation are essential to ensure graduates remain competitive in the job market. Moreover, cybersecurity threats are another critical consideration, necessitating robust measures to safeguard systems and protect student data. Financially, the cost of implementing IR 4.0 technologies and upgrading training facilities presents challenges for educational institutions, requiring careful budgeting and strategic planning.

Conversely, in Indonesia, TVET institutions are embracing technological advancements to enhance the learning process and adapt to a dynamic business environment shaped by IR 4.0. The emphasis is on continually updating technical skills and ensuring that human resources are adept at handling continuous technological changes. This proactive approach enables institutions to prepare students for career continuity in an increasingly digital and automated industrial landscape. By upgrading knowledge and skills, TVET institutions in Indonesia are ensuring that their graduates are well-equipped to meet the demands of IR 4.0 industries.

The discussions from the FGDs highlight the critical need for TVET institutions to continuously evaluate and adapt their training programs in response to the challenges and opportunities presented by IR 4.0. In Singapore, addressing technological

obsolescence and cybersecurity threats, while managing the financial implications of IR 4.0 implementation, are key priorities. Meanwhile, in Indonesia, focusing on upgrading technical skills and embracing technological advancements ensures that graduates are prepared for evolving industry needs. By maintaining a proactive stance towards continuous evaluation and adaptation, TVET institutions can effectively prepare their students for success in IR 4.0 industries, fostering a skilled and competitive workforce.

2.5.2 Industry

The outcomes from the FGD sessions with industry representatives revealed five predominant themes: positive changes and opportunities, challenges and preparedness, cybersecurity and connectivity, skill development and training, and government support.

Figure 7. Common themes from the FGD sessions with Industry representatives.

2.5.2.1 Positive changes and opportunities

The first common theme from the discussion among the industry representatives is the anticipation of positive changes from the implementation of IR 4.0 within industries, such as streamlining work processes, facilitating remote work capabilities, and enhancing efficiency in client service. There is optimism among industries regarding the opportunities presented by IR 4.0, viewing it as a catalyst for digitisation, automation, and innovation in products and services.

The FGD conducted among industry representatives in Thailand stated that they are actively embracing IR 4.0 as a means to reduce costs, increase production capabilities, and improve operational efficiency. Rather than viewing IR 4.0 as a challenge, Thai businesses perceive it as an inevitable opportunity to enhance their manufacturing capacities. The adoption of advanced technologies has streamlined complex tasks without reducing the workforce, emphasising the importance of personnel development and technological skills enhancement. This proactive approach ensures that every employee can effectively utilise digital tools for improved data analysis and operational efficiency.

In Malaysia, industries representatives' express optimism in adopting IR 4.0 technologies to transform their operations towards autonomous monitoring and task scheduling. This shift towards automation promises to reduce human intervention, enhance task efficiency, and optimise time management within industrial settings. The positive outlook reflects a readiness to embrace technological advancements for sustainable growth and competitiveness.

Similarly, in Lao PDR, industry experts recognise IR 4.0 as an opportunity to leverage advanced technologies and innovation across various facets of their operations. This includes easier access to information, enhanced digital marketing capabilities, and improved recruitment processes through social media platforms. The integration of new technologies is expected to drive economic growth by fostering innovation and increasing productivity within the industrial sector.

Participants from Indonesian industries perceive IR 4.0 as a user-friendly opportunity to enhance competitiveness through gradual digitisation and automation. By leveraging IR 4.0 technologies such as IoT and robotics, businesses aim to minimise human intervention in operations while facilitating seamless collaboration. This approach supports ongoing innovation projects and positions industries for sustained growth in a digitally-driven economy.

Industry representatives in Brunei demonstrate a strong awareness of IR 4.0's potential to drive digital transformation, automation, and data-driven decision-making within their organizations. Several companies have already initiated the adoption of IR

4.0 technologies such as AI, IoT, big data analytics, and cloud computing to enhance operational efficiency and maintain competitiveness in a rapidly evolving business landscape.

The discussions from the FGDs underscore the optimistic outlook of industries across Thailand, Malaysia, Lao PDR, Indonesia, and Brunei regarding the positive changes and opportunities brought forth by IR 4.0 implementation. These include improvements in operational efficiency, enhanced productivity, and the facilitation of innovation through advanced technologies. By embracing IR 4.0, industries in these countries are poised to adapt to technological advancements, optimise processes, and remain competitive in the global market, ensuring sustainable growth and economic resilience.

2.5.2.2 Challenges and preparedness

Although the first theme presents positive reactions regarding IR 4.0 adoption, the second theme underline the challenges faced by industries in adapting to IR 4.0, with the process requiring time and resources to build systems supportive of IR 4.0 skills. Despite recognising the importance of staying updated on client needs and innovation, varying levels of preparedness and response are observed among industries. Challenges include the lack of facilities, infrastructure, and human resources, hindering effective adoption of IR 4.0 principles and technologies.

In Lao PDR, while there is recognition of the potential benefits of IR 4.0, such as improved operational efficiency and job opportunities for skilled workers, there is also significant discomfort among companies and individuals who struggle to keep pace with technological changes. The challenges cited include a lack of experienced personnel proficient in utilising technology tools, which hinders effective adoption of IR 4.0 within the workforce. Additionally, the reluctance or inability of older business owners to adapt to new technologies poses further challenges in the implementation process.

Participants from Cambodia express concerns over the readiness of industries to adopt IR 4.0 skills, citing a significant gap between existing IR 3.0 skills and the

requirements of IR 4.0 technologies. The perception is that many industries are still catching up with previous technological advancements, making the leap to IR 4.0 more daunting. The infrastructure and support systems necessary to facilitate IR 4.0 skills development are still in nascent stages, requiring substantial time and investment to build a robust framework conducive to technological integration.

In Brunei, organisations face numerous challenges in transitioning to IR 4.0, with financial sustainability emerging as a primary concern. The high costs associated with implementing IR 4.0 technologies, including equipment investment, training costs, and system upgrades, pose significant barriers to adoption. Moreover, the shortage of skilled personnel capable of managing and leveraging new technologies exacerbates these challenges. Issues related to data security and privacy further complicate the transition process, emphasising the critical need for robust cybersecurity measures as industries embrace digital transformation.

The insights gathered from the FGDs in Lao PDR, Cambodia, and Brunei underscore the diverse challenges and varying levels of preparedness among industries in adopting IR 4.0 technologies. These challenges include financial constraints, lack of skilled personnel, infrastructure inadequacies, and concerns over data security. Addressing these challenges requires concerted efforts from industry stakeholders, policymakers, and educational institutions to foster a supportive environment for technological advancement. By overcoming these barriers through strategic investments in training, infrastructure development, and regulatory frameworks, industries can better position themselves to harness the opportunities presented by IR 4.0 and achieve sustainable growth in the digital age.

2.5.2.3 Cybersecurity and connectivity

The third theme highlights the importance of prioritising the cybersecurity measures and establishing reliable internet connectivity to protect sensitive data and support seamless digital operations.

In Thailand, the participants from industrial organisations emphasise the integration of technology across their operations, particularly in communication and real-time data

analysis for management purposes. While efforts have been made to ensure connectivity among devices within the organisation, complete remote access remains a challenge due to security concerns. Organisations have implemented platforms to manage access based on individual roles and responsibilities, reflecting a cautious approach to safeguarding sensitive data and maintaining operational integrity.

Malaysian industries are actively adapting to IR 4.0 by leveraging advanced technologies for remote maintenance and client interactions. Participants highlighted the rapid pace of technological advancements and the corresponding need for robust cybersecurity measures to protect against cyber threats. There is a strong emphasis on training and upskilling employees to handle evolving technologies effectively while ensuring compliance with cybersecurity regulations. This proactive approach aims to enhance operational efficiency and client satisfaction amid digital transformations.

In Lao PDR, the adoption of digital technologies is seen as a cost-saving measure and a means to introduce new service models. Industry experts underscore the benefits of digital networking systems that facilitate remote access and operational management from anywhere. The emphasis on technological integration reflects a strategic shift towards enhancing efficiency and reducing operational costs, supported by continuous advancements in digital capabilities and connectivity solutions.

Indonesia’s industries view IR 4.0 as pivotal for enhancing service delivery, operational efficiency, and competitiveness through technology adoption. The emphasis is placed on utilising technology to maintain consistent production quality, improve client engagement, and streamline processes. Despite the positive impact of IR 4.0, challenges persist in adapting to technological advancements among clients, necessitating continuous efforts in capacity building and digital literacy initiatives. Data collection and management remain integral, with ongoing enhancements to ensure industry readiness and responsiveness to market demands.

The insights from Thailand, Malaysia, Lao PDR, and Indonesia underscore the multifaceted approach industries are taking to navigate the complexities of IR 4.0 adoption. Key challenges include cybersecurity vulnerabilities, infrastructure

limitations, and the need for continual upskilling to harness the full potential of digital technologies. Addressing these challenges requires collaborative efforts among industry stakeholders, policymakers, and technology providers to establish robust cybersecurity frameworks and enhance connectivity infrastructure. By prioritising cybersecurity and connectivity, industries can mitigate risks, optimise operations, and capitalize on the opportunities presented by IR 4.0 to drive sustainable growth and innovation.

2.5.2.4 Skill development and training

Additionally, the industry representatives emphasise the need for employees to be proficient in IR 4.0 technologies, starting from TVET programmes and extending to continuous professional development initiatives. Upskilling and reskilling efforts are crucial for TVET teachers and administrators to ensure they are equipped to effectively integrate IR 4.0 technologies into education.

Industry representatives in Thailand are actively transforming their organisational vision to align with IR 4.0 imperatives. Top-level management plays a crucial role in setting directives and policies to integrate IR 4.0 technologies effectively. Significant budgets are allocated for IR 4.0 initiatives, encompassing areas such as materials, equipment, human resource development, communication, and internal management. This structured approach ensures that all departments are equipped to embrace technological advancements and support workforce upskilling efforts.

Malaysian industries emphasise the imperative of preparing students and upskilling workers to meet the demands of IR 4.0. Recognising the rapid pace of technological advancements, industries are committed to integrating the latest technologies into educational programs and continuous professional development initiatives. The focus remains on ensuring that the workforce is equipped with the necessary skills to remain competitive in the evolving industrial landscape driven by IR 4.0.

In Lao PDR, industry representatives mentioned that they are actively responding to IR 4.0 by adopting new technologies, educating employees, and developing

customized tools and platforms. Special budgets are allocated for research and development (R&D) to explore and implement IR 4.0-related innovations. The emphasis is on fostering a culture of innovation and digital transformation within organizations, supported by dedicated teams and committees tasked with overseeing digital initiatives and ensuring effective technology integration across operations.

Industry representatives from Indonesia underscores the critical role of workforce development in adapting to technological advancements and digital transformation. Continuous upskilling through workshops, research, and educational programs is prioritized to meet industry demands and enhance productivity. Periodic updates and adjustments are made to align with evolving technological trends, ensuring that the workforce remains adept at leveraging IR 4.0 technologies to drive organisational growth and competitiveness.

Cambodian industry leaders participated in the FGD session stress the importance of training employees starting from TVET programs through to continuous professional development. The focus is on enhancing workforce skills to meet market demands and adapt to IR 4.0 technologies effectively. This strategic approach aims to equip employees with the competencies required to produce high-quality products and services that align with industry standards and technological advancements.

Industry representatives from Brunei highlights the transformative impact of IR 4.0 on work practices, necessitating significant upskilling and reskilling efforts among employees. Emphasis is placed on integrating artificial intelligence (AI) into educational curricula from early stages to develop specialised skills. Training initiatives encompass areas like robotic process automation (RPA), enhancing operational efficiency through technology-driven solutions that minimize repetitive tasks and optimize workforce capabilities.

The insights from Thailand, Malaysia, Lao PDR, Indonesia, Cambodia, and Brunei underscore the multifaceted approaches industries are adopting to address skill development and training challenges in the era of IR 4.0. Key strategies include aligning educational programs with industry needs, investing in R&D for technology

adoption, fostering a culture of continuous learning and innovation, and integrating advanced technologies into workforce training. These efforts are crucial for preparing a skilled and adaptable workforce capable of thriving in the digitally-driven Fourth Industrial Revolution. Collaboration between industry stakeholders, educational institutions, and policymakers will be essential to sustain these initiatives and capitalise on the opportunities presented by IR 4.0 for economic growth and industrial competitiveness.

2.5.2.5 Government support

The last theme underscores the need for strengthening partnerships between TVET institutions, industry stakeholders, and the government to provide quality training courses and align curricula with industry needs. Government support, including resource allocation for infrastructure, staff training, and curriculum development, is crucial for the successful integration of IR 4.0 technologies and skills in educational institutions. Initiatives such as enhancing IR 4.0 capabilities and sustaining dialogue about IR 4.0-related issues through various venues for discussion are recommended to ensure continuous progress and adaptation.

Participants underscored the pivotal role of government support in preparing a skilled and adaptable workforce capable of thriving in the era of IR 4.0. Businesses articulated their expectations for government initiatives aimed at fostering a knowledgeable workforce through targeted resource allocation. This includes budgetary provisions for education, training programs, and upskilling opportunities that align with the evolving needs of the labor market. The government's proactive role in providing avenues for individuals to develop and enhance their competencies is seen as essential for national development. Stakeholders emphasised the need for sustained dialogue and collaboration between government bodies, educational institutions, and industries to ensure that training courses and curricula are effectively aligned with IR 4.0 technologies and industry requirements.

In Cambodia, participants echoed similar sentiments regarding the necessity of government support in preparing the workforce for IR 4.0 challenges. Representatives highlighted the importance of collaboration between the Ministry of Education and the Ministry of Labour and Vocational Training to enhance educational offerings and develop human resources capable of meeting IR 4.0 demands. Recommendations were made for the adaptation of IR 4.0 technologies within school curricula and the expansion of vocational training programs to equip students with relevant skills. This collaborative approach, supported by government resources and policy frameworks, is crucial for ensuring that TVET institutions can effectively integrate IR 4.0 capabilities into their educational frameworks.

The insights from Thailand and Cambodia underscore the critical role of government support in fostering effective partnerships between TVET institutions, industry stakeholders, and government bodies to facilitate the integration of IR 4.0 technologies and skills. Key recommendations include allocating resources for infrastructure development, staff training, and curriculum enhancement to align educational offerings with industry needs. Moreover, sustained dialogue and continuous engagement through various platforms are essential to address evolving challenges and opportunities presented by IR 4.0. By strengthening these partnerships and initiatives, Thailand and Cambodia can enhance their workforce readiness and competitiveness in the global digital economy, ultimately contributing to sustainable economic growth and development.

3.0 Discussions for Each Country

3.1 Brunei

In the Process category, TVET institutions assess three critical pillars: Curriculum, Stakeholder Engagement, and Teaching and Learning. The Curriculum pillar is foundational for preparing students for Industry 4.0 (IR 4.0). While general skills show promising progress, specialised skills lag behind. Institutions must update their curriculum to align with IR4.0 requirements, introduce specialised programmes, and

foster interdisciplinary learning to bridge this gap effectively. Effective Stakeholder Engagement is pivotal in adapting TVET programs to IR4.0. The current engagement levels with industrial and non-industrial stakeholders indicate room for improvement. Enhancing strategies to involve non-industrial stakeholders, such as local communities, can better align TVET programs with evolving societal and economic needs. The Teaching and Learning pillar, crucial for quality education, shows positive readiness. Institutions should further enhance teaching methods with innovative pedagogies and leverage technologies like AI to cultivate critical thinking and problem-solving skills among students. Professional development for educators in line with technological advancements is essential for sustained improvement.

Under the Technology category, TVET institutions evaluate Infrastructure, Intelligence, and Connectivity readiness. Moderate Infrastructure readiness suggests institutions are equipped adequately with digital resources. Regular updates and strategic investments are recommended to maintain alignment with technological advancements and ensure sustainable infrastructure. Intelligence readiness indicates opportunities for improvement in leveraging advanced technologies such as automation and machine learning. Investing in staff training and interdisciplinary collaboration can enhance capabilities in these areas significantly. Connectivity readiness reflects moderate preparedness in managing cyber security risks and ensuring digital interconnectivity. Continuous investment in secure communication infrastructure and proactive security measures is crucial to safeguarding sensitive data and maintaining uninterrupted operations.

In the Organisation category, focusing on Structure & Management and Talent Readiness is essential. Moderate readiness in Structure & Management highlights the need for clearer alignment of IR4.0 strategies with institutional vision and policies. Regular updates and a culture of innovation are vital for agility in adapting to technological changes. Talent Readiness, fundamental for successful IR4.0 adoption, shows moderate preparedness. Developing workforce capabilities through comprehensive training plans and engaging management support are critical. Building a capable taskforce and fostering a culture of continuous learning among staff are key for sustainable integration of IR4.0 initiatives.

In conclusion, preparing TVET institutions for IR4.0 entails addressing curriculum gaps, enhancing stakeholder engagement, leveraging technology effectively, strengthening infrastructure, aligning organizational strategies, and developing a skilled workforce capable of adapting to rapid technological advancements. These efforts are crucial for ensuring that TVET graduates are well-equipped for the evolving demands of the modern job market.

3.2 Cambodia

Findings highlight significant gaps in readiness across several factors. Under the Process factor, critical areas like Social skills, Artificial Intelligence (AI), machine learning, and Cybersecurity show limited preparation. Similarly, in the Technology factor, aspects such as Hardware Intelligence and Automation technology also indicate insufficient readiness. Organisational factors reveal challenges in embedding policies for IR 4.0 adaptation and assessing the current workforce's capability in adopting IR 4.0 technologies.

Empirical data underscore that TVET institutions in Cambodia require substantial investment in resources, including information technology and skilled experts, to enhance readiness for IR 4.0 skills. Industries face similar challenges and acknowledge the necessity of catching up with technological advancements through programs focused on programming, applied technologies, and automated production. The establishment of supporting systems and frameworks, such as the Cambodian school information system and digital policy frameworks, aims to address these gaps but requires rigorous implementation and support from the government.

The study’s findings align with existing literature highlighting regional concerns about IR 4.0 skills readiness in ASEAN countries. However, it also points out limitations, such as the relatively small number of participants from diverse roles within TVET institutions and limited representation from industries in focus group discussions. Future research should aim to broaden participation and conduct more comprehensive studies to provide deeper insights into these challenges.

To address these gaps, integrating Information Communication Technology (ICT) into formal education systems is crucial for introducing IR 4.0 skills to students effectively. Furthermore, developing professional development programs in collaboration with TVET institutions can upgrade the skills of existing employees to meet IR 4.0 demands. While existing policies and frameworks provide a foundation, careful construction of digital infrastructure is essential to align with the current expertise of employees and students.

Moving forward, a collaborative approach involving stakeholders such as industries, TVET institutions, and government bodies is necessary to identify common needs and solutions for advancing IR 4.0 skills. Rapid adaptation and integration of these skills into production and manufacturing processes could significantly boost economic growth in Cambodia, emphasising the urgency of addressing these readiness gaps promptly and comprehensively.

3.3. Indonesia

The Indonesian Ministry of Industry initiated the Indonesia Industry 4.0 Readiness Index (INDI 4.0) to assess industrial companies' readiness to digitalise production processes. This self-assessment tool, based on a scale of one to four, evaluates five key areas: organisational structure, employees, technology, production processes, and products/ services. Despite participation from over 300 companies, the average score ranged between 2.5 and 2.6, indicating a moderate level of readiness. However, specific details regarding industry sectors, company sizes, and future steps toward digital production were not disclosed by the ministry upon inquiry.

Indonesia, classified as a developing country, is in the process of adopting and adapting to IR 4.0 technologies within its TVET institutions and industrial sectors. Many industries still rely heavily on earlier industrial revolutions (IR 1.0, IR 2.0, and IR 3.0), characterised by labour-intensive practices. Consequently, TVET institutions continually adjust their curricula through industry synchronisation efforts to meet evolving technological demands and job market needs. Government initiatives such

as the revitalisation of Vocational High Schools and establishment of centers of excellence underscore Indonesia's commitment to aligning education with industry expectations.

Additionally, ongoing professional development programmes for TVET educators and administrators aim to enhance technical competencies and adaptability to technological advancements. The integration of Industry 4.0 technologies in teaching and learning practices within TVET institutions, including the use of adaptive learning applications and digital assessment tools, reflects efforts to prepare students effectively for the digital economy.

Despite having adequate technological infrastructure, TVET institutions often face challenges in maximising its utilisation due to gaps in knowledge and understanding. However, the adaptation of IR 4.0 technologies in collaboration with industry has shown promising results in fostering innovation and improving operational efficiencies. Nonetheless, there is a need for further training and capacity-building initiatives to optimise technological understanding and application across institutions and industries.

In organisational aspects, while some TVET institutions have incorporated IR 4.0 into their vision and mission statements, alignment with industry needs requires continuous evaluation and adjustment. Industry-led digital transformation teams play a crucial role in overseeing IR 4.0 implementation, emphasising the importance of strategic policies and frameworks to address future challenges effectively.

In summary, while Indonesia progresses towards Industry 4.0 integration, efforts in TVET institutions and industries focus on curriculum alignment, technological adaptation, and organisational alignment with evolving digital demands. Collaborative initiatives between government, institutions, and industries are essential to bridge existing readiness gaps and prepare a skilled workforce capable of thriving in the digital era.

3.4 Lao PDR

The integration of IR 4.0 skills into TVET curricula is underway, focusing on technical, soft, and entrepreneurial competencies to align with evolving job market demands. While initial adoption of IR 4.0 technologies like IoT and cloud computing is progressing, resource constraints remain a challenge. TVET institutions aim to equip students with essential skills through industry-aligned curricula. Collaboration between TVET institutions and industry stakeholders is regulated to enhance curriculum development, staff training, and skill-based assessments. This partnership ensures educational relevance by incorporating industry insights into teaching practices and refining curricula accordingly. Efforts also focus on enhancing teaching methods to foster practical skills development and improve students' ability to apply theoretical knowledge effectively.

Digital tools adoption for assessment in TVET is gradually increasing, emphasising authentic and performance-based evaluations. However, full integration is hindered by resource limitations and requires further development. Current digital infrastructure in TVET institutions, while moderately equipped, needs improvement to fully support IR 4.0 technologies and enhance educational delivery efficiency. TVET institutions cautiously explore automation features to enhance operational efficiency and decision-making. However, strategic investments in technology infrastructure and workforce skills are essential to fully leverage automation benefits. Cybersecurity measures are in place but require enhancement to address evolving threats adequately.

Despite functional digital inter-connectivity, seamless interoperability remains a challenge in TVET institutions, impacting collaborative efforts and operational efficiency. Institutional policies supporting IR 4.0 adoption need strengthening to facilitate comprehensive technology integration and competitiveness. IR 4.0 implementation offers significant opportunities for industry and TVET institutions, enhancing productivity and educational quality through advanced technologies. However, challenges such as workforce adaptation and technological integration must be addressed to maximise benefits and mitigate potential disruptions.

Overall, TVET institutions and industry sectors are preparing for IR 4.0 by upgrading infrastructure, investing in staff training, and adapting educational offerings. Strategic responses aim to align with industry advancements and foster sustained competitiveness in the digital era.

3.5 Malaysia

Based on the findings related to the readiness of TVET institutions in Malaysia for IR 4.0, several key insights emerge. In terms of process readiness, Malaysian TVET institutions show a moderate level of preparedness for IR 4.0. This suggests efforts to align organisational structures and management practices with the demands of IR 4.0 technologies, indicating awareness and initial adaptation to accommodate these changes.

Regarding technology readiness, TVET institutions demonstrate a similar moderate preparedness level. This is evidenced by the integration of IR 4.0 principles into core aspects such as the institution's purpose, vision, and mission, along with the establishment of policies facilitating technology adoption. However, there's still progress needed in fully embedding IR 4.0 frameworks across all technological dimensions. The organisational readiness block reveals insights into the overall readiness of TVET institutions, also reflecting a moderate level. While strides have been made to prepare institutions, gaps remain in having a capable task force and comprehensive training plans to equip the workforce adequately for IR 4.0 challenges. These findings underscore the need for further development in human resources and strategic policies to enhance readiness across Malaysian TVET institutions. Collaboration between institutions, industries, and governmental bodies is crucial to foster an environment conducive to technology adoption and integration.

Several studies reinforce these findings. Cheok and Ran (2022) highlight varying levels of readiness among institutions due to resource constraints, urging collaborative efforts for effective technology adoption. Abdullah et al. (2019) emphasise the importance of standardised guidelines and continuous professional development for educators to ensure uniform integration of IR 4.0 technologies in curricula. Gen et al.

(2022) identifies barriers like resistance to change and lack of technical support, proposing solutions such as faculty development and increased funding.

Furthermore, insights from Ibrahim et al. (2018) and others stress the importance of enhancing lecturer understanding and collaboration to effectively navigate IR 4.0 demands. The integration of IR 4.0 into educational curricula is seen as critical for developing graduates proficient in creativity, innovation, and critical thinking, crucial skills for global competitiveness (Azman & Ibrahim, 2018). In conclusion, the readiness of Malaysian TVET institutions for IR 4.0 requires a concerted effort to address identified gaps in process, technology, and organisation readiness. Stakeholders must prioritize collaboration, resource allocation, and continuous professional development to effectively prepare the workforce for the challenges and opportunities of the Fourth Industrial Revolution.

3.6 Philippines

Philippines TVET institutions are in the early stages of integrating IR 4.0 technologies into their curricula, with minimal content dedicated to IR 4.0 currently. This reflects a broader hesitancy among institutions to widely adopt IR 4.0, often citing its perceived inapplicability to their industries. However, there are varying levels of engagement from industry and non-industry stakeholders in promoting IR 4.0 within these institutions, with Technical Training Institutions (TTIs) generally showing minimal to sufficient engagement, while non-TTIs exhibit sufficient to more active involvement.

Regarding educational methodologies, some institutions have implemented blended learning schemes, either student-centred or teacher-centred, influenced significantly by the Technical Education and Skills Development Authority's (TESDA) deployment of the TESDA Online Program (TOP) nationwide. Assessment practices in TTIs primarily rely on traditional methods like written tests and practical demonstrations, whereas non-TTIs have started to incorporate IR 4.0 technologies in assessments, albeit on a limited scale. Despite this, there remains flexibility in digital tool selection for assessments among instructors.

Interviews with respondents reveal a positive perception of IR 4.0, viewed as essential for enhancing institutional and student competitiveness in the evolving global labour market. Some institutions have begun introducing "microcredentialing" to cater to the dynamic market needs, indicating proactive steps in curriculum adaptation. However, financial constraints and limited resources pose significant challenges to fully embracing IR 4.0. Many institutions lack sufficient funding and manpower to implement IR 4.0-related changes effectively. While digital infrastructures exist in varying capacities across institutions, there is underutilisation of advanced technologies such as intelligent automation and machine learning.

On an organisational level, IR 4.0's influence on the vision, mission, and policies of Philippine TVET institutions remains minor, with non-TTIs generally exhibiting clearer strategies and more robust task forces for IR 4.0 initiatives compared to TTIs. Nonetheless, both TTIs and non-TTIs express readiness to adopt IR 4.0 technologies despite the initial costs, acknowledging the long-term benefits for TVET and student employability. In conclusion, while Philippines TVET institutions have begun integrating IR 4.0 technologies into their educational frameworks, there is considerable room for improvement. Addressing financial constraints, enhancing digital infrastructure utilisation, and strengthening organisational strategies are crucial steps towards effectively preparing these institutions for the challenges and opportunities presented by IR 4.0.

3.7 Singapore

Key aspects of being future-ready include having robust technological infrastructure capable of supporting IR 4.0, including reliable network connectivity and secure IT systems. This infrastructure facilitates seamless integration of cutting-edge technologies into teaching and learning processes, enabling both students and teachers to leverage digital tools effectively. In terms of curriculum, a future-ready school integrates IR 4.0-related knowledge and skills across disciplines. This interdisciplinary approach encompasses digital literacy, computational thinking, problem-solving, critical thinking, creativity, and collaboration. Such a curriculum is designed to equip students with the competencies necessary to thrive in a digital and

dynamic world. The school's teaching methodologies prioritise learner-centered approaches that encourage active and collaborative learning. Educators utilise innovative pedagogies like project-based learning, experiential learning, and blended learning, often leveraging technologies such as augmented reality (AR) and virtual reality (VR) to enhance educational experiences. Teachers act as facilitators, guiding students to explore and apply their knowledge in real-world contexts.

Assessments in a future-ready school go beyond traditional academic evaluations to include real-world scenarios, problem-solving tasks, and performance-based assessments. These assessments are designed to measure students' ability to apply their skills in practical settings. Technology aids in streamlining assessment processes, ensuring objectivity, and providing timely feedback to students for continuous improvement. Collaboration with industry, research institutions, and the community is integral to a future-ready school. The school actively engages external stakeholders to align its curriculum with industry needs and job market demands. It promotes internships, apprenticeships, and industry attachments to provide students with hands-on experiences in authentic work environments.

Continuous professional development is emphasised for staff to enhance their technological proficiency, pedagogical skills, and understanding of IR 4.0 concepts. Through training, workshops, and collaboration with peers and experts, teachers are empowered to effectively integrate technology and innovative teaching strategies into their classrooms. Ultimately, a future-ready school prepares students to thrive in a future where technological advancements and digital transformation are pervasive. It equips them with the skills, knowledge, and mindset needed to adapt to evolving technologies and make meaningful contributions to society. By setting new educational standards, inspiring other institutions, and contributing to the broader evolution of the educational ecosystem, a future-ready school plays a pivotal role in shaping the future of education.

3.8 Thailand

The IR 4.0 curriculum of the institution encompasses a broad spectrum of transversal skills essential for navigating the Fourth Industrial Revolution's demands. Analysis of these skills indicates varying proficiencies among respondents. While complex problem-solving skills show moderate ratings with moderate variability, social skills are higher, suggesting well-developed capabilities on average. Process skills receive favourable ratings, indicating consistent proficiency across respondents, similar to findings by Punnitamai and Thepsumroeng (2022) highlighting their importance in administrative roles. Cognitive abilities and people management skills are moderately rated, reflecting some variability. In contrast, digital and entrepreneurial skills are viewed positively with narrower standard deviations, suggesting more consistent expertise, influenced by Thailand's emphasis on these skills in education (Meesuk, 2019).

Respondents demonstrate varied levels of familiarity with technology integration in the IR 4.0 curriculum. Big Data and Artificial Intelligence & Machine Learning receive moderate ratings with high standard deviations, indicating differing levels of familiarity. Autonomous Robotics and Smart Manufacturing score lower, suggesting limited understanding. Simulations, Internet of Things (IoT), Cloud Computing, and Cyber Security are moderately familiar, showing some response variation. Blockchain, however, receives lower scores, indicating limited knowledge, particularly in new technologies like Autonomous Robotics and Smart Manufacturing in Thailand, specific technologies (Niyomphol & Meesuk, 2019).

Regarding collaboration with industry stakeholders, respondents perceive curriculum alignment and skill-based assessment positively, with low standard deviations indicating strong agreement. Industrial attachment, staff training & development, and employment receive moderate ratings with variability in responses. Conversely, funding and shared facilities are rated lower with significant disagreement among respondents on effectiveness. Apprenticeships in IR 4.0 technologies also receive low ratings with high variability, reflecting mixed opinions on their impact. Thailand's emphasis on vocational education and the dual education model similar to Germany,

Work Integrated Learning (WIL), supports industrial attachment, according to the Organisation for Economic Co-operation and Development (OECD) (2021).

Collaboration with non-industry stakeholders reveals positive perceptions of service learning, skill-based assessment, and performance-based assessment with narrow standard deviations indicating agreement. Curriculum alignment, staff training & development, human resources, shared facilities, and certification receive moderate ratings with some variability. Industrial attachment, funding, and employment are moderately rated with varied perceptions. Research collaboration, though generally viewed positively, shows more variability in responses, similar to Niyomphol and Meesuk (2019), indicating increasing possibilities for research collaboration.

In assessing technological aspects, digital infrastructures are positively perceived with widespread agreement on their importance in education. The acceptance of technology in educational contexts influences teachers' intentions to use digital tools, as supported by Antonietti et al. (2022), who identified relationships between digital competence, ease of use, perceived usefulness, and technology adoption. Components of machine learning, such as data analysis, algorithms, and model building, show moderate perceptions with varied importance attributed to different aspects. Innovative technologies like gamification and cloud technology are well-received, while digital readers, tablets, and augmented reality/virtual reality show less significance, possibly due to limited implementation or understanding.

The organisation's alignment with the IR 4.0 framework, including Purpose, Vision, and Mission, is moderately perceived, indicating clarity but with variability in opinions. Institutional policies for IR 4.0-related technologies are moderately perceived to exist, while plans for IR 4.0 technology implementation show moderate perception with notable variability, reflecting differing strategies in managing organisations across small, medium, and large sectors in Thailand (Punnitamai & Thepsumroeng, 2022).

3.9 Vietnam

Based on the findings from surveys and stakeholder interviews, TVET institutions in Vietnam face several significant challenges as they strive to prepare for and integrate IR 4.0 technologies into their educational frameworks. Firstly, there is a pronounced socio-economic dimension where Vietnam grapples with a shortage of highly skilled workers, exacerbated by gender disparities, which could potentially lead to job displacement during the transition to IR 4.0. This underscores the urgent need for targeted strategies to address skills gaps and ensure inclusivity in technological adoption across genders.

Secondly, there is a noticeable lag in the adoption of IR 4.0 technologies within the classrooms of TVET institutions. This gap hinders the effective development of skills among students that are crucial for modern industries. Coupled with limited access to training materials focused on IR 4.0, trainees face challenges in acquiring up-to-date knowledge and competencies required by the evolving job market. This situation calls for enhanced curriculum development and resource allocation to bridge these gaps effectively.

Moreover, there exists a significant mismatch between the skills imparted by TVET institutions and the actual demands of industries. This mismatch complicates the alignment between graduate capabilities and workforce needs, emphasising the necessity for closer collaboration between educational institutions and industry stakeholders to ensure curriculum relevance and workforce readiness.

Furthermore, the lack of incentives for businesses to engage in partnerships with TVET institutions further exacerbates the gap in teaching and training related to IR 4.0 technologies. Without adequate collaboration and support from industry, institutions struggle to update their educational offerings and align them with industry standards and technological advancements.

In response to these challenges, Vietnam's Politburo introduced Resolution No. 52-NQ/TW, which outlines comprehensive guidelines aimed at transforming the

educational landscape to embrace IR 4.0 effectively. This resolution emphasises the importance of cultivating digital literacy, scientific knowledge, and technological innovation within educational curricula. It calls for the integration of essential digital and foreign language skills, adoption of innovative teaching methodologies leveraging digital technologies, and continuous improvement of policies to attract and nurture high-quality human resources.

Additionally, Resolution No. 52-NQ/TW encourages increased research and development activities, promotes industry collaboration, and advocates for international partnerships. These initiatives are intended to position Vietnam's educational system at the forefront of technological advancement, ensuring that graduates are well-prepared to thrive in the digital age. By implementing these guidelines, Vietnam aims to enhance its national competitiveness, foster economic growth, and equip its workforce with the skills necessary to succeed in an increasingly technology-driven global economy.

4.0 Implications and Policy Recommendations

Enhancing Digitalisation and IR 4.0 Adoption

Continuous collaborative efforts between TVET institutions and industries are essential for enhancing the adoption of digitalisation and IR 4.0. By sharing experiences and best practices, these entities can synergise their efforts, addressing and reducing mismatches between educational outcomes and industry needs. This collaboration ensures that both educational programs and industry practices evolve in tandem, fostering a more integrated and effective approach to digital transformation.

Assessment and Readiness Tools

Given the absence of a comprehensive assessment tool, the SERI assessment matrix is recommended as a robust instrument for gauging readiness for IR 4.0. The current survey results can serve as a foundational step in crafting a detailed roadmap toward IR 4.0 adoption. This roadmap will guide institutions through the necessary stages of development and implementation. Additionally, a policy brief outlining these recommendations will be circulated to policymakers, advocating for the adoption of SERI as a standard assessment tool.

Qualitative Methods

Incorporating qualitative methods, such as interviews and focus group discussions, can provide valuable insights into the nuanced perspectives and experiences of various stakeholders. While the use of these methods is not mandatory, they offer a depth of understanding that complements quantitative data. Institutions can decide to utilise these approaches based on their specific needs and contexts, ensuring that the insights gained are relevant and actionable.

Action and Enhancement Plan

Developing a comprehensive action or enhancement plan is crucial. This plan, created in conjunction with the roadmap, should include a clear timeline and precise activities aimed at advancing the institution to the next level of IR 4.0 adoption. The plan should

outline specific goals, strategies, and milestones, providing a structured approach to digital transformation and ensuring that progress is measurable and achievable.

Policy Recommendations to Ministries of Education in ASEAN Member States

To ensure a coordinated effort across the region, it is recommended that the Ministries of Education in ASEAN Member States adopt the SERI assessment matrix as a tool for assessing and monitoring the progress of educational institutions' readiness for digitalisation and IR 4.0. SERI can be used as a regular monitoring tool, with assessments conducted annually, biannually, or triannually. This regular assessment can become part of the accreditation process, ensuring that institutions maintain a consistent focus on digital readiness.

Policy Recommendations to TVET Institutions in ASEAN Member States

TVET institutions should utilise the SERI assessment matrix as a self-assessment tool to gauge their current level of readiness for digitalisation. This assessment will provide a detailed overview of the institution’s status across various levels, including processes, technology, organisation, and dimensions (spanning 8 pillars and 19 dimensions). Based on the initial assessment, institutions can then develop strategic action plans to progress to higher levels of IR 4.0 adoption. The following table offers a practical guide for institutions to follow.

Table 21. Sample of action plans.

IMPROVEMENT PLAN **BLOCK - *PROCESS*** **PILLAR - *CURRICULUM*** **DIMENSION - *TRANSVERSAL SKILLS***		
Current level: 2/Learner-Moderate usage with IR 4.0 Curriculum (Curriculum content adopts basic components of IR 4.0)		
Next level: 3/Experienced-Almost every time expose/ use IR 4.0 Curriculum (Curriculum content incorporates majority components of IR 4.0)		
Activity	**Timeline**	**Target**
Integrating transversal skills in curriculum	6 months	Fifty percent courses have integrated transversal skills in their curricukum
Integrating transversal skills in teaching-learning	6 months	Fifty percent courses have integrated transversal skills in teaching-learning
Integrating transversal skills in assessment	6 months	Fifty percent courses have integrated transversal skills in their assessment
Notes	There is a long list of tranversal skills. The transversal skills to be focused on for this period are complex problem solving, social skills, and digital skills.	

Dual Assessment Approach

To gain a comprehensive understanding of the readiness for IR 4.0, it is ideal to assess both TVET institutions and industries. This dual assessment approach allows for monitoring and examining the alignment between educational preparations and industry needs. By understanding both perspectives, stakeholders can ensure that educational institutions are effectively preparing students for the demands of the digital transformation and that these preparations align with industry expectations. This comprehensive view facilitates a more cohesive and effective transition to IR 4.0 across both education and industry sectors.

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