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Technology Management Towards Industry 4.0: Basis for the Integration of Industry 4.0 Competencies into the Tvet Curriculum

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ABSTRACT: The Fourth Industrial Revolution, or Industry 4.0, has transformed workplace technologies and increased the demand for workers with advanced digital, technical, and problem-solving competencies. Technical and Vocational Education and Training (TVET) institutions play an essential role in preparing learners for emerging industry requirements. This study assessed technology management towards Industry 4.0 as a basis for integrating Industry 4.0 competencies into the TVET curricula of selected institutions. Specifically, it determined the level of technology management and readiness of selected TVET schools for Industry 4.0 adoption and integration. Data were gathered from identified respondents using a structured questionnaire covering technological infrastructure, technology planning, utilisation and maintenance, faculty and trainer competencies, institutional support, and industry linkages. Existing Industry 4.0-related competencies and priority competencies needed by TVET learners were also assessed. Frequency, percentage, weighted mean, and standard deviation were used to summarize the data, while a one-sample t-test determined whether mean ratings significantly differed from the neutral value of 3.00. Results showed moderate technology management ($M = 2.67$, $SD = 0.95$) and high readiness for Industry 4.0 adoption and integration ($M = 3.87$, $SD = 0.72$). The findings indicated a need to strengthen digital infrastructure, technology management practices, faculty and trainer competencies, technology-based teaching and learning, and industry linkages. Priority competencies included automation and robotics, Internet of Things (IoT), data analytics, artificial intelligence, cloud computing, cybersecurity, digital problem-solving, and smart manufacturing. The study concludes that effective technology management provides a strong foundation for systematically integrating Industry 4.0 competencies into TVET curricula. A curriculum enhancement framework emphasizing infrastructure, human resource development, digital pedagogy, industry collaboration, and continuous technology upgrades is recommended.

INTRODUCTION

Technology management is essential in preparing institutions and their graduates for the rapidly changing requirements of Industry 4.0. In the TVET context, technology management involves the systematic planning, acquisition, utilization, maintenance, evaluation, and improvement of technological resources, infrastructure, human capabilities, and educational processes. The emergence of digital manufacturing, robotics, automation, artificial intelligence (AI), the Internet of Things (IoT), cloud computing, data analytics, and other smart technologies has transformed workplace practices and created new competency requirements. Consequently, TVET institutions need effective technology management systems to determine

whether their facilities, equipment, faculty capabilities, training programs, and institutional practices are sufficiently responsive to technological developments. Effective management of technology can also provide a basis for identifying competencies that should be incorporated into TVET curricula to produce graduates who are digitally competent, adaptable, innovative, and prepared for emerging employment opportunities.

This study, entitled "Technology Management Towards Industry 4.0: Basis for the Integration of Industry 4.0 Competencies into the TVET Curriculum," focuses on selected TVET schools in the Third District of Cebu, particularly those located in Toledo City, Pinamungajan, and Balamban. It assesses the current level of technology management and the readiness of these institutions to adopt and integrate Industry 4.0 technologies and practices. Specifically, it considers technological infrastructure and facilities, technology planning and acquisition, technology utilization and maintenance, faculty and trainer competencies, institutional support, and industry linkages. The study also examines existing Industry 4.0-related competencies integrated into TVET programs and identifies the priority competencies needed by learners. The findings are intended to provide an empirical basis for curriculum enhancement and the development of an Industry 4.0 competency integration framework that responds to technological and workforce requirements.

The increasing importance of digital and technological competencies in TVET has been emphasized by international organizations and researchers. The International Labour Organization (ILO) recognizes that technological change affects occupations, production processes, employment patterns, and the skills required by workers (International Labour Organization, 2020). It emphasizes that digitalization of TVET should involve broader transformation of skills systems rather than merely transferring traditional learning activities to digital platforms. Similarly, UNESCO-UNEVOC emphasizes the necessity for TVET institutions to strengthen digital competencies, modernize learning environments, and continuously develop teachers and trainers. In the Philippine context, competency mapping and alignment with emerging technological requirements are increasingly important to ensure that TVET graduates possess relevant and industry-responsive skills.

Despite these developments, limited empirical studies examine how technology management within specific TVET institutions can serve as a foundation for Industry 4.0 curriculum integration, particularly at the local level. Existing studies often focus on national policies, general Industry 4.0 trends, or technological applications without sufficiently examining institutional readiness, infrastructure, faculty capabilities, industry partnerships, and curriculum conditions simultaneously. This study therefore addresses the need for localized evidence from TVET institutions in Cebu's Third District. Its findings may assist administrators, curriculum developers, faculty members, trainers, learners, and industry partners in identifying technology-management gaps and priority competencies. Ultimately, the study seeks to contribute to a more responsive, technology-driven, industry-aligned, and future-ready TVET curriculum capable of supporting workforce development and regional economic growth.

LITERATURE REVIEW

Industry 4.0 has brought significant changes to workplaces, production systems, education, and skills development, creating an increasing demand for digital, technical, and technology-related competencies among learners and workers (International Labor Organization, 2020; UNESCO-UNEVOC, 2020; OECD, 2018). through automation, artificial intelligence, robotics, the Internet of Things, big data, cloud computing, and digital manufacturing. These developments require Technical-Vocational Education and Training (TVET) institutions to strengthen technology management and develop graduates with digital, technical, adaptive, innovative, and problem-solving competencies. Technology management involves the planning, acquisition, utilisation, maintenance, monitoring, and improvement of technologies, facilities, human resources, and instructional processes. emphasize that TVET digitalization requires institutional transformation, continuous teacher development, appropriate infrastructure, and alignment with changing labor-market requirements. In the Philippine context, Republic Act No. 7796, or the Technical Education and Skills Development Act of 1994, supports responsive and demand-driven skills development while promoting competency standards and qualification alignment. Republic Act No. 10647, or the Ladderised Education Act, further supports lifelong learning, upskilling, reskilling, and pathways between TVET and higher education.

The study is anchored on Socio-Technical Systems Theory. TAM explains how perceived usefulness and ease of use affect the adoption of technology, while Diffusion of Innovations explains how new technologies spread within institutions. Socio-technical systems theory emphasises the interaction of technology, people, organizational structures, and institutional processes. Literature further indicates that successful Industry 4.0 integration requires digital infrastructure, competent faculty and trainers,

institutional support, industry partnerships, flexible curricula, and performance-based learning. However, limited studies have examined these factors simultaneously in specific TVET institutions in Toledo City, Pinamungajan, and Balamban, Cebu. This gap supports the present study, which assesses technology management and Industry 4.0 readiness as bases for integrating relevant competencies into the TVET curriculum and developing future-ready, industry-responsive graduates.

Definition of Terms

This section presents the operational and conceptual meanings of the key terms used in the study. It is positioned at the end of the introduction, immediately before the objectives, to provide clarity and establish a common understanding of the major concepts examined in the research.

Automation. The use of programmed technologies and control systems to perform tasks with minimal human intervention.

Cloud Computing. Internet-based computing services used for storage, applications, collaboration, and data management.

Cybersecurity. The protection of digital systems, networks, and data from unauthorized access, attacks, and misuse.

Data Analytics. The process of collecting, processing, and interpreting data for decision-making and problem-solving.

Digital Infrastructure. Hardware, software, networks, internet connectivity, and digital platforms supporting learning and operations.

Digital Literacy. The ability to effectively, safely, and responsibly use digital technologies and information.

Industry 4.0 Competencies. Technical, digital, analytical, innovative, problem-solving, and adaptive skills required to use Industry 4.0 technologies.

Industry Linkages. Partnerships between TVET institutions and industries for training, curriculum development, immersion, and technology support.

Internet of Things (IoT). Connected devices and sensors that collect, exchange, and process data through networks.

Lifelong Learning. Continuous development of knowledge, skills, and competencies throughout education and employment.

Machine Learning. An AI process that enables systems to learn patterns from data and improve performance.

Robotics. The design, programming, and operation of programmable machines or robots for automated tasks.

Smart Manufacturing. Manufacturing using interconnected digital technologies, automation, sensors, AI, and data analytics.

Technology Management. The systematic planning, acquisition, utilization, maintenance, monitoring, and improvement of technological resources and capabilities.

Technology Readiness. The extent to which an institution has the infrastructure, human resources, curriculum, support, and partnerships needed for Industry 4.0 adoption.

Technical-Vocational Education and Training (TVET). Education and training that develops technical knowledge, practical skills, and competencies for employment and industry requirements.

OBJECTIVES

1. Evaluate the level of technology management in selected TVET schools in Toledo City, Pinamungajan, and Balamban in terms of:
1.1. Technological infrastructure and facilities;
1.2. Technology planning and acquisition;
1.3. Technology utilization and maintenance;
1.4. Faculty and trainer competencies; and
1.5. Institutional support and industry linkages.

2. Assess the readiness of the selected TVET schools to adopt and integrate Industry 4.0 technologies and practices.

3. Determine the existing Industry 4.0 competencies incorporated into the TVET curriculum and training programs of the selected schools.

4. Identify the priority Industry 4.0 competencies required by TVET learners to address emerging technological and industry demands.

5. Develop an Industry 4.0 competency integration framework or curriculum enhancement plan based on the study's findings to strengthen the integration of relevant Industry 4.0 competencies into the TVET curriculum.

MATERIALS AND METHODS

Design

The study employed a descriptive-evaluative research design using a quantitative approach to assess technology management and Industry 4.0 readiness among selected Technical and Vocational Education and Training (TVET) schools in Toledo City, Pinamungajan, and Balamban, Cebu. The design enabled the researchers to determine the existing level of technology management, institutional readiness, Industry 4.0 competencies integrated into the curriculum, and priority competencies needed by TVET learners.

Environment

The study was conducted in selected TVET schools located in Toledo City, Pinamungajan, and Balamban, Cebu. These areas served as the study locale because they represented TVET institutions operating within Cebu's Third District and provided relevant contexts for examining technology management, technology adoption, curriculum integration, and industry responsiveness.

Respondents

The study population consisted of 150 respondents from selected TVET schools in Toledo City, Pinamungajan, and Balamban, comprising TVET graduates, technology instructors, and industry experts. A purposive sampling technique was employed to select participants who had direct knowledge and experience relevant to technology management and Industry 4.0 competencies. The sample size of 150 was determined based on the identified target population and the inclusion criteria established for the study. The respondents were distributed as follows: 120 TVET graduates, 20 technology instructors, and 10 industry experts. This composition provided relevant perspectives from major stakeholders for assessing technology management, Industry 4.0 readiness, and the competencies needed for integration into the TVET curriculum. Of the 150 respondents, 120 or 80.00% were TVET graduates, 20 or 13.33% were technology instructors, and 10 or 6.67% were industry experts. The predominance of TVET graduates allows the study to capture the experiences and perceptions of the primary beneficiaries of technology-oriented education and training, while the participation of technology instructors and industry experts provides complementary perspectives on instructional implementation and workplace requirements. This respondent composition is important in assessing the alignment of TVET programs with the changing demands of Industry 4.0, particularly in terms of technological competencies, digital readiness, curriculum responsiveness, and industry expectations. The International Labour Organization (ILO) highlights the need to strengthen TVET institutions' capacity to address digital transformation and changing labor-market demands, while UNESCO-UNEVOC emphasizes the development of teacher, trainer, and curriculum competencies aligned with the requirements of the Fourth Industrial Revolution (International Labour Organization, 2020; UNESCO-UNEVOC, 2020). Thus, the inclusion of graduates, instructors, and industry experts provides a relevant foundation for assessing technology management, Industry 4.0 readiness, existing competencies, and priority competencies for TVET curriculum enhancement.

Instrument

The researchers used a structured questionnaire as the primary data-gathering instrument, consisting of five parts aligned with the objectives of the study.

Part I gathered the respondents' profiles.

Part II assessed the level of technology management in terms of technological infrastructure and facilities, technology planning and acquisition, technology utilization and maintenance, faculty and trainer competencies, institutional support, and industry linkages.

Part III determined the level of readiness of the selected TVET schools for the adoption and integration of Industry 4.0 technologies and practices.

Part IV identified the existing Industry 4.0-related competencies integrated into the TVET curriculum and training programs and determined the priority competencies needed by TVET learners.

Part V included a checklist of Industry 4.0 technologies, practices, and competencies currently implemented in the selected schools.

The instrument used appropriate rating scales to quantify the respondents' assessments and provided the data needed to develop a competency integration framework or curriculum enhancement plan.

Validation of the Instrument

The research instrument was submitted to experts in TVET, technology management, Industry 4.0, and curriculum development for content validation. Their recommendations were incorporated to improve the clarity, relevance, organization, and appropriateness of the questionnaire items. A pilot test was conducted with respondents who were excluded from the actual study, and the reliability of each section of the questionnaire was evaluated using Cronbach's alpha. The pilot test involved [pilot sample size] respondents, and a minimum Cronbach's alpha coefficient of 0.70 was adopted as the criterion for acceptable internal consistency.

Data-Gathering Procedure

Prior to data collection, the researchers secured the necessary permissions from the concerned school administrators and authorities. After approval, the validated questionnaire was administered to the identified respondents. The purpose of the study was explained, and the respondents were informed that their participation was voluntary and that their responses would be treated confidentially. The accomplished questionnaires were collected, checked for completeness, encoded, tabulated, and prepared for statistical analysis.

Treatment of Data

The data were analyzed using appropriate descriptive statistics. Frequency and percentage were used to describe the respondents and identify existing Industry 4.0 technologies, practices, and competencies. Weighted mean and standard deviation were used to determine the level of technology management and Industry 4.0 readiness. Ranking was used to identify and prioritize the Industry 4.0 competencies required by TVET learners. To determine whether the observed levels differed significantly from the neutral value of 3.00, a one-sample t-test was also employed, with the corresponding t-value, degrees of freedom (df), and p-value reported in the Results section. The findings served as the basis for developing a competency integration framework or curriculum enhancement plan for strengthening Industry 4.0 integration in the TVET curriculum.

Ethical Considerations

The study observed the principles of informed consent, voluntary participation, confidentiality, privacy, and responsible data management. Respondents were informed about the purpose and procedures of the study before participation, and no personally identifiable information was disclosed in the presentation of results. The data gathered were used solely for academic and research purposes.

RESULTS AND DISCUSSION

The findings indicate that the study was primarily represented by TVET graduates (80.00%), complemented by technology instructors (13.33%) and industry experts (6.67%), providing learner, instructional, and workplace perspectives. The results in Table 2 indicated a moderate level of technology management (M = 2.67, SD = 0.95) with weaknesses in technological infrastructure, internet connectivity, technology planning, and industry linkages. These results indicate the need to strengthen digital infrastructure, technology acquisition and maintenance, faculty development, institutional support, and school-industry

collaboration. In contrast, Table 3 showed a high level of Industry 4.0 readiness (M = 3.87, 77.48%, SD = 0.72), particularly in digital infrastructure, faculty and trainer readiness, and curriculum and training readiness. However, industry and partnership readiness obtained the lowest dimension mean (M = 3.67), indicating the need for stronger industry-based training and collaboration. Table 4 further showed that Industry 4.0 competencies were highly integrated into existing TVET curricula (M = 3.75, 75.00%, SD = 0.78), particularly problem-solving and technology-based innovation, digital literacy, and CAD/digital manufacturing. Nevertheless, AI applications were only moderately integrated (M = 3.35), indicating the need to strengthen advanced competencies such as AI, robotics, cybersecurity, and intelligent systems. Table 5 identified Industry 4.0 competencies as a very high priority (M = 4.26, 85.16%, SD = 0.67), led by advanced digital skills, technology-based innovation, automation, robotics, IoT, and continuous learning. This indicates a need to expand existing curriculum provisions toward advanced and emerging technologies. Finally, Table 6 provides a systematic framework for curriculum enhancement through readiness assessment, competency mapping, curriculum integration, faculty development, infrastructure support, industry-based learning, performance assessment, and continuous improvement. Overall, the findings support the integration of Industry 4.0 competencies into the TVET curriculum, reinforced by effective technology management, updated technological facilities, competent faculty and trainers, and sustained academe–industry partnerships.

Thematic Statement

The findings showed that technology management served as a critical foundation for Industry 4.0 readiness, although gaps remained in infrastructure, technology planning, equipment maintenance and utilization, faculty capability, and industry linkages. The selected TVET schools demonstrated a generally high level of institutional readiness, with existing strengths in digital infrastructure, faculty and trainer readiness, curriculum and training, and institutional support, while industry partnerships remained the principal gap requiring further strengthening.

Industry 4.0 competencies such as digital literacy, IoT, automation, robotics, data analytics, cloud computing, cybersecurity, CAD, digital manufacturing, and technology-based innovation were already integrated into TVET programs, although artificial intelligence required further strengthening. The findings also indicated a very high priority for advanced competencies, particularly in AI, IoT, automation and robotics, data analytics, cybersecurity, smart manufacturing, adaptability, and technology-based problem-solving.

The results further supported the development of a competency integration framework that strengthened curriculum alignment, faculty development, digital infrastructure, industry-based learning, performance-based assessment, and continuous curriculum improvement. The one-sample t-test results showed statistically significant differences from the neutral value of 3.00, with exact *p*-values reported in the corresponding results table 2. Technology management was significantly below the neutral level (M = 2.67), while institutional readiness (M = 3.87), existing Industry 4.0 competency integration (M = 3.75), and priority competencies (M = 4.26) were identified as the priority areas for Industry 4.0 competency integration into the TVET curriculum.

Figures

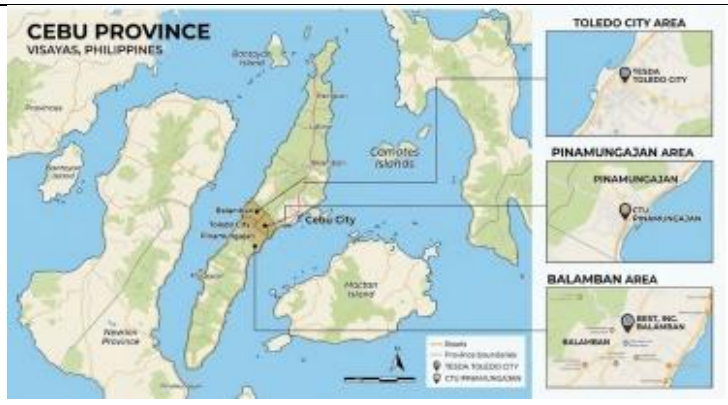

Figure 1. Location Map of the Research Environment

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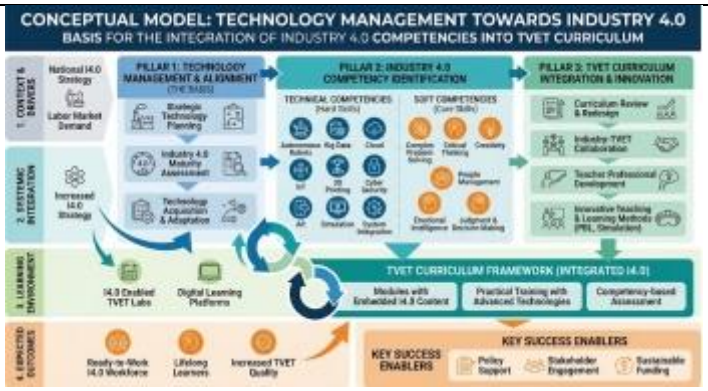

Figure 2. Conceptual Model

Table 1. Distribution of Respondents

N=150

Group of Respondents	Frequency (f)	Percentage (%)
TVET Graduates	120	80.00
Technology Instructors	20	13.33
Industry Experts	10	6.67
Total	**150**	**100**

Table 2. Level of Technology Management in Selected TVET Schools

N=150

Indicators of Technology Management	5	4	3	2	1	Mean	Percentage (%)	SD	Interpretation
A. Technological Infrastructure and Facilities									
1. Availability of adequate technological infrastructure and facilities	3	12	45	70	20	2.39	47.73	0.89	Low Level of Technology Management
2. Accessibility of computers and digital equipment	5	15	50	60	20	2.50	50.00	0.96	Low Level of Technology Management
3. Availability of reliable internet connectivity	2	10	38	65	35	2.19	43.87	0.91	Low Level of Technology Management
4. Availability of updated technological equipment	4	14	42	66	24	2.39	47.73	0.95	Low Level of Technology Management
5. Adequacy of facilities for technology-based training	3	13	44	68	22	2.38	47.60	0.91	Low Level of Technology Management

B. Technology Planning and Acquisition								
1. Existence of technology plans aligned with institutional goals	6	18	52	56	18	2.59	51.73	0.98	Low Level of Technology Management
2. Systematic identification of technology needs	5	20	55	52	18	2.61	52.27	0.97	Moderate Level of Technology Management
3. Appropriate budgeting for technology acquisition	4	17	50	58	21	2.50	50.00	0.96	Low Level of Technology Management
4. Acquisition of updated and relevant technologies	5	16	48	60	21	2.49	49.87	0.97	Low Level of Technology Management
5. Consideration of Industry 4.0 technologies in technology planning	2	12	40	64	32	2.25	45.07	0.93	Low Level of Technology Management
C. Technology Utilization and Maintenance									
1. Regular utilization of available technologies in teaching and training	8	25	60	45	12	2.81	56.27	0.98	Moderate Level of Technology Management
2. Proper operation and handling of technological equipment	10	28	62	40	10	2.92	58.40	0.99	Moderate Level of Technology Management
3. Regular preventive maintenance of technological equipment	5	20	55	55	15	2.63	52.67	0.95	Moderate Level of Technology Management
4. Timely repair and replacement of defective equipment	4	18	50	60	18	2.53	50.67	0.94	Low Level of Technology Management
5. Efficient use of digital technologies in training activities	9	24	58	48	11	2.81	56.27	0.99	Moderate Level of Technology Management
D. Faculty and Trainer Competencies									
1. Faculty and trainers possess adequate digital skills	10	30	65	38	7	2.99	59.73	0.95	Moderate Level of Technology Management
2. Faculty and trainers use technology effectively in instruction	12	32	62	38	6	3.04	60.80	0.97	Moderate Level of Technology Management
3. Faculty and trainers participate in technology-related training	8	26	60	48	8	2.85	57.07	0.95	Moderate Level of Technology Management
4. Faculty and trainers demonstrate awareness of Industry 4.0 technologies	6	24	58	52	10	2.76	55.20	0.94	Moderate Level of Technology Management
5. Faculty and trainers apply emerging technologies in training activities	7	25	60	48	10	2.81	56.13	0.95	Moderate Level of Technology Management
E. Institutional Support									

1. School administrators provide support for technology integration	11	30	63	40	6	3.00	60.00	0.96	Moderate Level of Technology Management
2. Adequate resources are provided for technology-based instruction	8	26	58	48	10	2.83	56.53	0.97	Moderate Level of Technology Management
3. Professional development opportunities in emerging technologies are provided	5	20	55	58	12	2.65	53.07	0.92	Moderate Level of Technology Management
4. Institutional policies support technology adoption	9	28	60	45	8	2.90	58.00	0.96	Moderate Level of Technology Management
5. The school encourages innovation and technology-based practices	10	29	62	42	7	2.95	59.07	0.96	Moderate Level of Technology Management
F. Industry Linkages									
1. The school maintains active partnerships with industry	7	22	58	52	11	2.75	54.93	0.95	Moderate Level of Technology Management
2. Industry partners provide technology-related training opportunities	5	18	52	60	15	2.59	51.73	0.94	Low Level of Technology Management
3. Industry partners contribute to curriculum and competency development	4	17	50	62	17	2.53	50.53	0.93	Low Level of Technology Management
4. Students are exposed to current industry technologies through partnerships	6	20	54	57	13	2.66	53.20	0.95	Moderate Level of Technology Management
5. Industry linkages support the adoption of Industry 4.0 technologies	3	15	48	65	19	2.45	49.07	0.91	Low Level of Technology Management
Overall						**2.67**	**53.45**	**0.95**	**Moderate Level of Technology Management**

Table 3. Level of Readiness for the Adoption and Integration of Industry 4.0 Technologies and Practices

N-150

Readiness Attributes	5	4	3	2	1	Mean	Percentage (%)	SD	Interpretation
1. Digital Infrastructure Readiness						4.02	80.40	0.67	High Level of Readiness
1.1 Availability of reliable digital infrastructure	37	47	15	1	0	4.20	84.00	0.72	High Level of Readiness
1.2 Availability of high-speed internet connectivity	22	62	15	1	0	4.05	81.00	0.64	High Level of Readiness
1.3 Availability of computers and digital devices	30	55	15	0	0	4.15	83.00	0.66	High Level of Readiness

1.4 Availability of smart and connected equipment	10	54	34	2	0	3.72	74.40	0.67	High Level of Readiness
1.5 Accessibility of digital learning platforms	23	54	23	0	0	4.00	80.00	0.68	High Level of Readiness
2. Faculty and Trainer Readiness						3.91	78.20	0.70	High Level of Readiness
2.1 Digital literacy of faculty and trainers	34	52	12	2	0	4.18	83.60	0.72	High Level of Readiness
2.2 Knowledge of Industry 4.0 technologies	15	56	28	1	0	3.85	77.00	0.67	High Level of Readiness
2.3 Ability to use emerging technologies in instruction	18	58	20	4	0	3.90	78.00	0.73	High Level of Readiness
2.4 Participation in Industry 4.0-related training	11	52	31	6	0	3.68	73.60	0.75	High Level of Readiness
2.5 Capability to develop technology-based learning activities	18	59	23	0	0	3.95	79.00	0.64	High Level of Readiness
3. Curriculum and Training Readiness						3.90	78.00	0.71	High Level of Readiness
3.1 Integration of digital technologies into training programs	23	57	19	1	0	4.02	80.40	0.68	High Level of Readiness
3.2 Integration of automation and smart technologies	11	51	35	3	0	3.70	74.00	0.70	High Level of Readiness
3.3 Inclusion of Industry 4.0 competencies in learning outcomes	19	52	27	2	0	3.88	77.60	0.73	High Level of Readiness
3.4 Availability of technology-based practical activities	15	56	25	4	0	3.82	76.40	0.73	High Level of Readiness
3.5 Alignment of training programs with emerging industry requirements	31	49	19	1	0	4.10	82.00	0.73	High Level of Readiness
4. Institutional Readiness and Support						3.86	77.20	0.71	High Level of Readiness
4.1 Institutional policies support Industry 4.0 adoption	23	53	20	4	0	3.95	79.00	0.77	High Level of Readiness
4.2 Adequate budget for emerging technologies	8	46	44	2	0	3.60	72.00	0.67	High Level of Readiness
4.3 Administrative support for digital transformation	22	62	15	1	0	4.05	81.00	0.64	High Level of Readiness

4.4 Availability of professional development programs	14	54	28	4	0	3.78	75.60	0.73	High Level of Readiness
4.5 Institutional support for technology innovation	21	51	27	1	0	3.92	78.40	0.72	High Level of Readiness
5. Industry and Partnership Readiness						3.67	73.40	0.70	High Level of Readiness
5.1 Active partnerships with technology-oriented industries	10	48	39	3	0	3.65	73.00	0.70	High Level of Readiness
5.2 Industry participation in curriculum development	13	48	35	4	0	3.70	74.00	0.75	High Level of Readiness
5.3 Availability of industry-based technology training	5	53	37	5	0	3.58	71.60	0.67	High Level of Readiness
5.4 Opportunities for learners to experience current industry technologies	14	53	32	1	0	3.80	76.00	0.68	High Level of Readiness
5.5 Industry support for Industry 4.0 technology adoption	9	48	39	4	0	3.62	72.40	0.71	High Level of Readiness
OVERALL	**456**	**1,330**	**657**	**57**	**0**	**3.87**	**77.48**	**0.72**	**High Level of Readiness**

Table 4. Existing Industry 4.0-Related Competencies Integrated into the TVET Curriculum and Training Programs

N = 150

Industry 4.0 Competencies	5	4	3	2	1	Mean	Percentage (%)	SD	Interpretation
1. Digital literacy and digital communication	30	52	18	0	0	4.12	82.40	0.69	Highly Integrated
2. Internet of Things (IoT) applications	10	57	30	3	0	3.74	74.80	0.68	Highly Integrated
3. Automation and control systems	12	41	44	3	0	3.62	72.40	0.74	Highly Integrated
4. Robotics and programmable systems	6	45	40	9	0	3.48	69.60	0.75	Highly Integrated
5. Data analytics and data management	15	51	33	1	0	3.80	76.00	0.70	Highly Integrated
6. Artificial Intelligence (AI) applications	5	39	43	12	1	3.35	67.00	0.80	Moderately Integrated
7. Cloud computing and digital platforms	13	50	33	4	0	3.72	74.40	0.74	Highly Integrated
8. Cybersecurity and data protection	8	35	50	7	0	3.44	68.80	0.74	Highly Integrated
9. Computer-aided design and digital manufacturing	29	48	22	1	0	4.05	81.00	0.74	Highly Integrated
10. Problem-solving and technology-based innovation	32	55	12	1	0	4.18	83.60	0.67	Highly Integrated
OVERALL	**160**	**473**	**325**	**41**	**1**	**3.75**	**75.00**	**0.78**	**Highly Integrated**

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Table 5. Priority Industry 4.0 Competencies Needed by TVET Learners

N = 150

Priority Industry 4.0 Competencies	5	4	3	2	1	Mean	Percentage (%)	SD	Interpretation
1. Digital literacy and advanced digital skills	47	47	5	1	0	4.40	88.00	0.64	Very High Priority
2. Internet of Things (IoT) and connected systems	45	42	13	0	0	4.32	86.40	0.69	Very High Priority
3. Automation, robotics, and intelligent systems	41	53	6	0	0	4.35	87.00	0.59	Very High Priority
4. Artificial Intelligence and machine learning	40	48	12	0	0	4.28	85.60	0.67	Very High Priority
5. Data analytics and visualization	38	46	16	0	0	4.22	84.40	0.70	Very High Priority
6. Cloud computing and digital collaboration	29	57	14	0	0	4.15	83.00	0.64	High Priority
7. Cybersecurity and data privacy	27	57	15	1	0	4.10	82.00	0.67	High Priority
8. Smart manufacturing and digital production	25	58	17	0	0	4.08	81.60	0.65	High Priority
9. Technology-based problem-solving and innovation	48	42	10	0	0	4.38	87.60	0.66	Very High Priority
10. Adaptability and continuous technology learning	44	43	12	1	0	4.30	86.00	0.72	Very High Priority
OVERALL	**384**	**493**	**120**	**3**	**0**	**4.26**	**85.16**	**0.67**	**Very High Priority**

Table 6. Proposed Framework

N-150

Framework Component	Key Activities	Industry 4.0 Competencies to Integrate	Proposed Curriculum Enhancement	Expected Output
1. Readiness and Needs Assessment	Assess digital infrastructure, faculty capability, equipment, software, and institutional readiness	Digital literacy, technology awareness, digital communication	Conduct annual Industry 4.0 readiness and competency-gap assessment	Industry 4.0 readiness profile
2. Competency Identification and Mapping	Identify existing and priority competencies based on study findings and industry requirements	Automation, IoT, data analytics, AI, robotics, cloud computing, cybersecurity, CAD/CAM, digital collaboration	Map Industry 4.0 competencies against existing course learning outcomes	Industry 4.0 competency map
3. Curriculum Integration	Embed competencies into appropriate TVET subjects and practical training	Digital problem-solving, automation, IoT, data management, simulation, smart manufacturing	Revise course outcomes, modules, laboratory activities, and assessment tasks	Enhanced TVET curriculum

4. Foundational Digital Competencies	Strengthen basic and intermediate digital skills	Digital literacy, digital productivity, cybersecurity awareness, digital communication	Integrate foundational competencies across first-year courses	Digitally competent learners
5. Technical Industry 4.0 Competencies	Introduce hands-on technology applications	IoT, sensors, PLC/automation, robotics, CAD/CAM, 3D printing, AI, data analytics	Develop technology-based laboratory activities and projects	Industry 4.0-ready technical skills
6. Data and Intelligent Technology Competencies	Develop learners' ability to collect, process, analyze, and interpret data	Data analytics, AI fundamentals, cloud computing, machine learning concepts	Integrate data-driven activities, dashboards, simulations, and predictive applications	Data-literate TVET graduates
7. Cybersecurity and Digital Safety	Develop safe and responsible technology practices	Cybersecurity, data privacy, network security, digital ethics	Include cybersecurity and data protection activities in relevant courses	Responsible and secure technology users
8. Industry-Based Learning	Strengthen collaboration with industries and technology partners	Digital teamwork, innovation, problem-solving, technology adaptation	Implement OJT, industry projects, demonstrations, immersion, and workplace-based learning	Industry-responsive competencies
9. Faculty Development	Upgrade faculty knowledge and skills in emerging technologies	Technology integration, digital pedagogy, automation, AI, IoT, data analytics	Conduct training, certification, industry immersion, and faculty upskilling	Industry 4.0-capable faculty
10. Technology Infrastructure Support	Provide appropriate hardware, software, connectivity, and laboratory facilities	Digital infrastructure management, networked systems, smart laboratory operations	Prioritize laboratories, internet connectivity, devices, sensors, automation kits, and software	Technology-enabled learning environment
11. Performance-Based Assessment	Assess actual application of Industry 4.0 competencies	Technical proficiency, digital problem-solving, innovation, collaboration	Use performance tasks, simulations, projects, portfolios, demonstrations, and competency assessments	Validated Industry 4.0 competencies
12. Monitoring and Continuous Improvement	**Evaluate implementation and update competencies**	**Lifelong learning, adaptability, innovation, continuous digital upskilling**	**Conduct annual curriculum review based on technology trends, industry feedback, and learner performance**	**Continuously improved Industry 4.0 curriculum**

CONCLUSION

The study concludes that the selected TVET schools have moderate technology management (M = 2.67) but high Industry 4.0 readiness (M = 3.87), indicating that institutional readiness is stronger than the existing technology-management foundation. Industry 4.0 competencies are already highly integrated (M = 3.75), although AI and other advanced technologies require greater

emphasis. The very high priority rating (M = 4.26) for Industry 4.0 competencies confirms the need to strengthen learners' digital, technical, analytical, innovative, and adaptive capabilities. The findings further support the need to improve technology management while strengthening the integration of Industry 4.0 competencies into the TVET curriculum. maximizing existing institutional readiness. The proposed Industry 4.0 Competency Integration Framework provides a systematic basis for curriculum enhancement through competency mapping, infrastructure development, faculty training, industry collaboration, performance-based assessment, and continuous improvement.

RECOMMENDATIONS

The study recommends strengthening technology management, infrastructure, connectivity, equipment, technology planning, budgeting, and maintenance; providing continuous faculty and trainer development in AI, IoT, automation, robotics, data analytics, cybersecurity, computer-aided design and computer-aided manufacturing (CAD/CAM), digital manufacturing, with particular attention to artificial intelligence (AI)integration. TVET schools should formally map Industry 4.0 competencies into course outcomes, laboratory activities, practical training, and assessments; strengthen industry partnerships through internships, immersion, curriculum development, equipment support, and workplace projects; and expand project-based and performance-based learning. Annual readiness and competency-gap assessments should guide planning and curriculum updates. The proposed framework should be pilot-tested, evaluated, and continuously improved, curriculum developers, and industry stakeholders supporting its implementation. Future researchers should conduct broader studies using larger samples and additional statistical analyses.

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REFERENCES

[1] International Labour Organization. (2022). Skills for a greener future: Challenges and enabling factors to achieve a just transition. International Labour Office.

[2] International Labour Organization. (2023). The digital transformation of TVET: Challenges and opportunities. International Labour Office.

[3] Paryono, P., & Mashod, M. (2025). TVET readiness for Industry 4.0 and digital transformation in Southeast Asia. Southeast Asian Ministers of Education Organization Regional Centre for Vocational and Technical Education and Training.

[4] Rogers, E. M. (2003). Diffusion of innovations (5th ed.). Free Press.

[5] Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, 13(3), 319–340. https://doi.org/10.2307/249008

[6] Bostrom, R. P., & Heinen, J. S. (1977). MIS problems and failures: A socio-technical perspective. Part I: The causes. MIS Quarterly, 1(3), 17–32. https://doi.org/10.2307/248710

[7] Schwab, K. (2016). The fourth industrial revolution. World Economic Forum.

[8] World Economic Forum. (2020). The future of jobs report 2020. World Economic Forum.

[9] World Economic Forum. (2023). The future of jobs report 2023. World Economic Forum.

[10] United Nations Educational, Scientific and Cultural Organization. (2015). Recommendation concerning technical and vocational education and training (TVET). UNESCO.

[11] UNESCO-UNEVOC. (2020). Trends mapping study: Digitalization and TVET. UNESCO-UNEVOC International Centre for Technical and Vocational Education and Training.

[12] UNESCO-UNEVOC. (2021). Understanding the impact of digital technologies on TVET. UNESCO-UNEVOC International Centre for Technical and Vocational Education and Training.

[13] Philippine Congress. (1994). Republic Act No. 7796: Technical Education and Skills Development Act of 1994. Technical Education and Skills Development Authority.

[14] Philippine Congress. (2014). Republic Act No. 10647: An act strengthening the ladderized interface between technical-vocational education and training and higher education. Official Gazette of the Republic of the Philippines.

[15] Technical Education and Skills Development Authority. (2020). TESDA 4.0: Transforming technical vocational education and training for the Fourth Industrial Revolution. TESDA.

[16] Technical Education and Skills Development Authority. (2023). National technical education and skills development plan 2023–2028. TESDA.

[17] Department of Education. (2022). Basic education development plan 2030. Department of Education, Republic of the Philippines.

[18] Philippine Qualifications Framework–National Coordinating Council. (2018). Philippine Qualifications Framework handbook. Philippine Qualifications Framework.

[19] International Labour Organization. (2021). Skills for a resilient future: Technical and vocational education and training in the context of COVID-19. International Labour Office.

[20] World Bank. (2020). Realizing the future of learning: From learning poverty to learning for everyone, everywhere. World Bank.

[21] Asian Development Bank. (2021). Innovative strategies for technical and vocational education and training in Asia. Asian Development Bank.

[22] Asian Development Bank. (2022). Skills development and technical and vocational education and training in the digital economy. Asian Development Bank.

[23] International Organization for Standardization. (2018). ISO 45001:2018: Occupational health and safety management systems—Requirements with guidance for use. ISO.

[24] International Labour Organization. (2024). World employment and social outlook: Trends 2024. International Labour Office.

[25] World Economic Forum. (2025). The future of jobs report 2025. World Economic Forum.