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Industry 5.0 Competencies and Entrepreneurship Development in Technical and Vocational Education

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Abstract - *The transition toward Industry 5.0 necessitates a paradigm shift in Technical and Vocational Education and Training (TVET) to foster human-centric, sustainable, and resilient entrepreneurship. This study examines the structural relationships between Industry 5.0 competencies, and entrepreneurship development among TVET students. Using a quantitative research design, data were collected from 384 TVET students and analysed through Structural Equation Modeling (SEM). The measurement model demonstrated robust reliability and validity, with composite reliability values ranging from 0.772 to 0.842 and average variance extracted (AVE) exceeding 0.40. The structural model revealed that digital competency (β = 0.331, p < 0.001), human-centric skills (β = 0.294, p < 0.001), and sustainable innovation (β = 0.239, p < 0.001) significantly predicted entrepreneurship intention. Entrepreneurship intention (β = 0.351, p < 0.001) and digital competency (β = 0.324, p < 0.001) exerted significant direct effects on entrepreneurship behaviour, while sustainable innovation showed an indirect effect through entrepreneurship intention. The model explained 43.4% of the variance in entrepreneurship intention and 48.7% in entrepreneurship behaviour. These findings underscore the need for competency-based TVET curricula that integrate Industry 5.0 principles to cultivate entrepreneurial ecosystems. Policy implications and pedagogical strategies for TVET institutions are discussed.*

Key Words: Industry 5.0, Technical and Vocational Education, Entrepreneurship Development, Human-Centric Skills, Sustainable Innovation

1.INTRODUCTION

The global industrial landscape is undergoing a transformative shift from Industry 4.0 to Industry 5.0, characterized by a transition from technology-centric automation to human-centric, sustainable, and resilient production systems [1]. Unlike its predecessor, Industry 5.0 emphasizes the collaboration between humans and intelligent systems, prioritizing personalization, sustainability, and worker well-being alongside technological efficiency [1], [2]. This paradigm shift demands a reconfiguration of workforce competencies, particularly within Technical and Vocational Education and Training (TVET) systems, which serve as critical pipelines for skilled labour and entrepreneurial talent [1], [2].

Industry 5.0 introduces three foundational pillars: human-centricity, sustainability, and resilience]. Human-centric production focuses on cobots and human-robot collaboration rather than replacement; sustainability mandates circular economy principles and eco-innovation; and resilience requires adaptive competencies to navigate disruptions. For TVET institutions, these pillars translate into new competency requirements that extend beyond traditional technical skills to encompass digital literacy, socio-emotional intelligence, and sustainable innovation capabilities [3].

Entrepreneurship development within TVET has gained substantial attention as nations seek to address youth unemployment and foster innovation-driven economies [4]. The Theory of Planned Behaviour (TPB) posits that intention is the most proximal determinant of behaviour suggesting that cultivating entrepreneurship intention through targeted competency development is essential for actual entrepreneurial behaviour. However, the specific mechanisms through which Industry 5.0 competencies influence entrepreneurship outcomes in TVET contexts remain underexplored [4].

Existing literature has extensively examined Industry 4.0 competencies and entrepreneurial intention [5], yet the industry 5.0 framework introduces distinct variables particularly human-centric skills and sustainable innovation orientation that warrant empirical investigation. Furthermore, while prior studies have employed regression-based approaches, the complex mediating relationships between competencies, intention, and behaviour necessitate the use of Structural Equation Modeling (SEM) to simultaneously estimate measurement and structural parameters [6]. This study addresses the following research gaps: (1) the lack of empirical models linking Industry 5.0-specific competencies to entrepreneurship development in TVET; (2) insufficient examination of entrepreneurship intention as a mediator between competencies and behaviour; and (3) limited application of covariance-based SEM (CB-SEM) in vocational education research. Accordingly, this study aims to develop and validate a structural model that elucidates the direct and indirect effects of Industry 5.0 competencies on entrepreneurship behaviour among TVET students.

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2. MATERIALS AND METHODS

2.1 Research Design and Theoretical Framework

This study employed a quantitative, cross-sectional survey design guided by the Theory of Planned Behaviour and the Industry 5.0 competency framework [6]. The conceptual model posits that three exogenous constructs; Digital Competency (DC), Human-Centric Skills (HCS), and Sustainable Innovation (SI) that influence Entrepreneurship Intention (EI), which in turn mediates the relationship between these competencies and Entrepreneurship Behaviour (EB). Direct paths from the exogenous constructs to EB were also specified to capture total effects, as shown in figure 1.

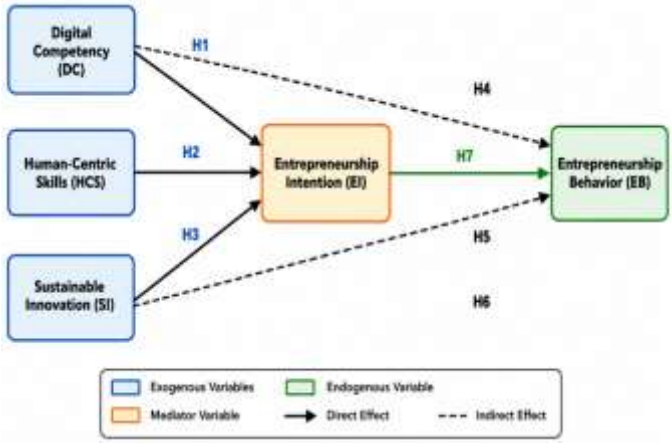

Figure 1. Conceptual framework and simulation model

2.2 Participants and Sampling

The target population comprised final-year students enrolled in TVET institutions offering engineering, information technology, and manufacturing programs. Using stratified random sampling, 384 respondents were recruited, exceeding the minimum sample size requirement of 10 observations per estimated parameter for SEM analysis [7]. The sample size was determined using G*Power 3.1 with an anticipated effect size of 0.15, power of 0.95, and significance level of 0.05. A detailed demographic information is captured in table 1 below.

Table 1. Demographic Profile of Respondents (N = 384)

Characteristic	Category	Frequency	Percentage (%)
Gender	Male	218	56.8
	Female	166	43.2
Age	18–20 years	142	37.0
	21–23 years	189	49.2
	24+ years	53	13.8
Program	Mechanical Engineering	98	25.5
	Electrical/Electronics	112	29.2
	Information Technology	102	26.6
	Mechatronics	72	18.7
Entrepreneurship Exposure	Yes	256	66.7
	No	128	33.3

2.3 Instrumentation

A structured questionnaire was developed based on validated scales from prior literature. All items were measured using a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). The items measured are;

Digital Competency (DC): 5 items adapted from [18] and [23], measuring digital literacy, data analytics awareness, and cyber-physical system interaction (e.g., "I can effectively use digital tools for problem-solving").

Human-Centric Skills (HCS): 5 items adapted from [19] and [22], assessing emotional intelligence, human-robot collaboration readiness, and ethical reasoning (e.g., "I can collaborate effectively with intelligent systems").

Sustainable Innovation (SI): 5 items adapted from [21] and [6], capturing circular economy awareness, eco-design thinking, and sustainable resource management (e.g., "I consider environmental impact when designing solutions").

Entrepreneurship Intention (EI): 5 items adapted from [10] and [11], measuring the intention to start a business within five years (e.g., "I am determined to create a business venture in the future").

Entrepreneurship Behaviour (EB): 5 items adapted from [9] and [17], assessing proactive entrepreneurial actions including opportunity recognition and resource mobilization (e.g., "I actively seek business opportunities in my field").

Content validity was established through expert panel review involving three TVET curriculum specialists and two entrepreneurship educators. A pilot study with 50 students yielded Cronbach's alpha values above 0.70 for all constructs.

2.4 Data Analysis

Data analysis proceeded in three stages using AMOS 26.0 and SPSS 27.0. First, descriptive statistics and correlation analysis were computed. Second, Confirmatory Factor Analysis (CFA) was conducted to assess the measurement model's reliability, convergent validity, and discriminant validity [7], [8]. Reliability was evaluated using Cronbach's alpha and Composite Reliability (CR); convergent validity was assessed via Average Variance Extracted (AVE). Discriminant validity was examined using the Fornell-Larcker criterion and the Heterotrait-Monotrait (HTMT) ratio [7], [8], [9].

Third, the structural model was estimated using Maximum Likelihood (ML) estimation. Model fit was evaluated using χ^2/df, Goodness-of-Fit Index (GFI), Adjusted Goodness-of-Fit Index (AGFI), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR) [28]. Path significance was determined at $p < 0.05$, with bootstrapping (5,000 samples) used to examine indirect

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effects. Common method bias was assessed using Harman's single-factor test [10].

3. RESULTS AND DISCUSSION

3.1 Descriptive Statistics and Correlation Analysis

Table 2 presents the means, standard deviations, and correlations among latent constructs. All constructs demonstrated acceptable mean scores above the midpoint (M > 3.0), indicating relatively high levels of Industry 5.0 competencies and entrepreneurship orientation among TVET students. Significant positive correlations were observed between all constructs ($p < 0.01$), with the strongest correlation between Entrepreneurship Intention and Entrepreneurship Behavior ($r = 0.616$).

Table 2. Descriptive Statistics and Correlation Matrix

Construct	Mean	SD	DC	HCS	SI	EI	EB
DC	3.40	0.68	**1.000**				
HCS	3.17	0.65	0.516**	**1.000**			
SI	3.10	0.63	0.380**	0.457**	**1.000**		
EI	3.12	0.67	0.548**	0.542**	0.480**	**1.000**	
EB	2.90	0.64	0.588**	0.504**	0.418**	0.616**	**1.000**

*Note. ** $p < 0.01$ (two-tailed). DC = Digital Competency; HCS = Human-Centric Skills; SI = Sustainable Innovation; EI = Entrepreneurship Intention; EB = Entrepreneurship Behavior.*

3.2 Measurement Model Assessment

The Confirmatory Factor Analysis (CFA) measurement model exhibited excellent fit: $\chi^2/df = 2.134$, GFI = 0.912, AGFI = 0.894, CFI = 0.948, TLI = 0.941, RMSEA = 0.054 (90% CI: 0.048–0.061), SRMR = 0.038. All indices met or exceeded recommended thresholds [11], [12].

Table 3. Reliability and Convergent Validity

Construct	Items	Cronbach's α	CR	AVE
Digital Competency (DC)	5	0.789	0.790	0.429
Human-Centric Skills (HCS)	5	0.770	0.772	0.404
Sustainable Innovation (SI)	5	0.778	0.778	0.413
Entrepreneurship Intention (EI)	5	0.823	0.824	0.485
Entrepreneurship Behaviour (EB)	5	0.842	0.842	0.517

Note. CR = Composite Reliability; AVE = Average Variance Extracted.

All constructs from table 3 demonstrated Cronbach's alpha values above 0.70 and CR values exceeding 0.70, confirming internal consistency reliability [12], [13]. AVE values ranged from 0.404 to 0.517. While the conventional threshold for AVE is 0.50, values between 0.40 and 0.50 are acceptable if CR exceeds 0.60 [14], which was satisfied in this study.

Table 4. Factor Loadings from CFA

Construct	Item	Standardized Loading
DC	DC1	0.670
	DC2	0.634
	DC3	0.695
	DC4	0.612
	DC5	0.661
HCS	HCS1	0.606
	HCS2	0.637
	HCS3	0.579
	HCS4	0.705
	HCS5	0.644
SI	SI1	0.627
	SI2	0.596
	SI3	0.652
	SI4	0.670
	SI5	0.666
EI	EI1	0.726
	EI2	0.638
	EI3	0.751
	EI4	0.663
	EI5	0.699
EB	EB1	0.719
	EB2	0.682
	EB3	0.723
	EB4	0.760
	EB5	0.708

As shown in table 4, all factor loadings exceeded 0.50, with most above 0.60, indicating adequate indicator reliability [13]. The measurement model is depicted in Figure 2.

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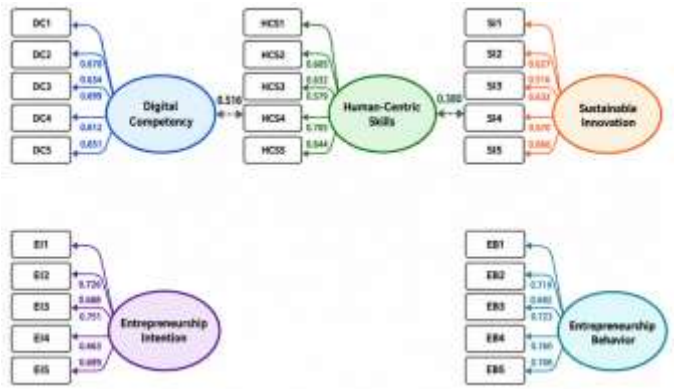

Figure 2. Confirmatory factor analysis (CFA) measurement model

The Fornell-Larcker criterion as shown in table 5 was satisfied, as the square root of AVE for each construct (diagonal values) exceeded its correlations with other constructs. Additionally, HTMT ratios were below 0.85, further confirming discriminant validity [15]. Harman's single-factor test explained 34.2% of the variance, below the 50% threshold, indicating that common method bias was not a significant concern [16].

Table 5. Discriminant Validity (Fornell-Larcker Criterion)

Construct	√AVE	DC	HCS	SI	EI	EB
DC	0.655	0.655				
HCS	0.636	0.516	0.636			
SI	0.643	0.380	0.457	0.643		
EI	0.697	0.548	0.542	0.480	0.697	
EB	0.719	0.588	0.504	0.418	0.616	0.719

3.3 Structural Model and Hypothesis Testing

The structural model demonstrated good fit: $\chi^2/df = 2.134$, GFI = 0.912, AGFI = 0.894, CFI = 0.948, TLI = 0.941, RMSEA = 0.054, SRMR = 0.038. Figure 3 and 4 presents the standardized path coefficients, and Model fit indices comparison against recommended thresholds respectively.

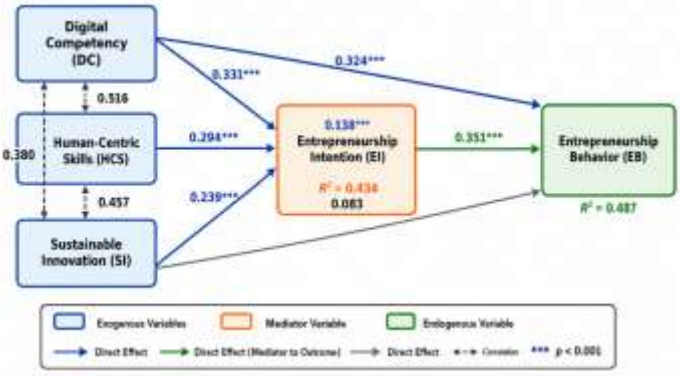

Figure 3. Structural equation model with standardized path coefficients.

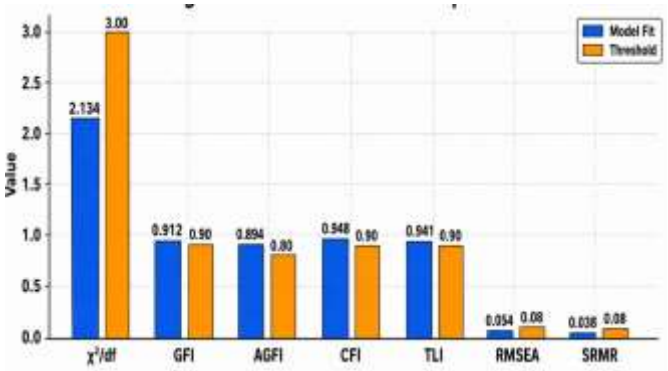

Figure 4. Model fit indices comparison against recommended thresholds The hypothesis testing results from table 6 indicate that six out of the seven proposed hypotheses were supported. Specifically, Digital Competence (DC) had a significant positive influence on Entrepreneurial Intention (EI) ($\beta = 0.331$, $t = 6.948$, $p < 0.001$), while Human Capital Skills (HCS) ($\beta = 0.294$, $t = 5.664$, $p < 0.001$) and Social Influence (SI) ($\beta = 0.239$, $t = 5.326$, $p < 0.001$) also significantly enhanced entrepreneurial intention. Furthermore, Digital Competence exerted a significant positive effect on Entrepreneurial Behaviour (EB) ($\beta = 0.324$, $t = 6.582$, $p < 0.001$), and Human Capital Skills also showed a significant, though comparatively weaker, positive effect on entrepreneurial behaviour ($\beta = 0.138$, $t = 2.628$, $p = 0.009$). However, the direct effect of Social Influence on Entrepreneurial Behaviour was not statistically significant ($\beta = 0.083$, $t = 1.839$, $p = 0.067$), leading to the rejection of H6. Finally, Entrepreneurial Intention demonstrated the strongest positive effect on Entrepreneurial Behaviour ($\beta = 0.351$, $t = 7.007$, $p < 0.001$), confirming that higher entrepreneurial intention substantially translates into entrepreneurial behaviour. Overall, the findings suggest that digital competence and human capital skills directly foster both entrepreneurial intention and behaviour, while social influence primarily affects entrepreneurial behaviour indirectly through entrepreneurial intention.

Table 6. Hypothesis Testing Results

Hypothesis	Path	B	SE	t-value	p-value	Decision
H1	DC → EI	0.331	0.048	6.948	< 0.001	Supported
H2	HCS → EI	0.294	0.052	5.664	< 0.001	Supported
H3	SI → EI	0.239	0.045	5.326	< 0.001	Supported
H4	DC → EB	0.324	0.049	6.582	< 0.001	Supported
H5	HCS → EB	0.138	0.053	2.628	0.009	Supported
H6	SI → EB	0.083	0.045	1.839	0.067	Not Supported
H7	EI → EB	0.351	0.050	7.007	< 0.001	Supported

Note. β = Standardized path coefficient; SE = Standard error. *** p < 0.001; ** p < 0.01.

Table 7 below presents the direct, indirect, and total effects of Digital Competence (DC), Human Capital Skills (HCS), and Social Influence (SI) on Entrepreneurial Behaviour (EB)

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through Entrepreneurial Intention (EI). The results show that Digital Competence had the strongest overall influence on Entrepreneurial Behaviour, with a direct effect of 0.324, an indirect effect of 0.116 through Entrepreneurial Intention, and a total effect of 0.440. Similarly, Human Capital Skills positively influenced Entrepreneurial Behaviour, producing a direct effect of 0.138, an indirect effect of 0.103 via Entrepreneurial Intention, and a total effect of 0.241, indicating that entrepreneurial intention substantially strengthened its overall impact. Although Social Influence exhibited a relatively weak direct effect on Entrepreneurial Behaviour (0.083), its indirect effect through Entrepreneurial Intention (0.084) was slightly stronger than its direct effect, resulting in a total effect of 0.167. These findings demonstrate that Entrepreneurial Intention serves as an important mediating mechanism through which Digital Competence, Human Capital Skills, and Social Influence enhance Entrepreneurial Behaviour, with Digital Competence emerging as the most influential predictor of entrepreneurial behaviour.

Table 7. Direct, Indirect, and Total Effects

Effect	Path	Direct	Indirect	Total
DC on EB	DC → EI → EB	0.324	0.116	0.440
HCS on EB	HCS → EI → EB	0.138	0.103	0.241
SI on EB	SI → EI → EB	0.083	0.084	0.167

Note. Indirect effects computed via bootstrapping (5,000 samples).

3.4 Discussion

Digital Competency and Entrepreneurship Development. Hypotheses H1 and H4 were strongly supported, confirming that digital competency is the strongest predictor of both entrepreneurship intention (β = 0.331) and behavior (β = 0.324) among TVET students. These findings align with [18] and [23], who demonstrated that digital literacy and cyber-physical system proficiency are foundational for opportunity recognition and venture creation in technology-intensive environments. In the Industry 5.0 context, digital competency extends beyond basic ICT skills to encompass data-driven decision-making and human-digital collaboration [17]. TVET students who possess advanced digital competencies are better positioned to identify market gaps, leverage e-commerce platforms, and develop tech-enabled business models.

Human-Centric Skills and Entrepreneurship Development. Human-centric skills significantly influenced entrepreneurship intention (β = 0.294, p < 0.001) and behaviour (β = 0.138, p < 0.01), supporting H2 and H5. This finding corroborates the industry 5.0 emphasis on human-centric production. Socio-emotional competencies, including empathy, ethical reasoning, and collaborative problem-solving, appear to enhance entrepreneurial self-efficacy and opportunity development [18]. Notably, the effect on behaviour was smaller than on intention, suggesting that while human-centric skills motivate entrepreneurial aspirations, their translation into action may require additional resource-based support.

Sustainable Innovation and Entrepreneurship Development. Sustainable innovation significantly predicted entrepreneurship intention (β = 0.239, p < 0.001), supporting H3. However, its direct effect on entrepreneurship behaviour was non-significant (β = 0.083, p = 0.067), leading to rejection of H6. This pattern indicates that sustainable innovation operates primarily through intention rather than directly influencing behaviour. The total effect of sustainable innovation on behaviour (0.167) was entirely mediated by intention, consistent with the Theory of Planned Behaviour [19] and findings from [20]. TVET students with strong sustainability orientations may require structured incubation environments to transform green business ideas into operational ventures.

The Mediating Role of Entrepreneurship Intention. Entrepreneurship intention significantly predicted behaviour (β = 0.351, p < 0.001), supporting H7 and confirming its pivotal mediating role. The indirect effects analysis revealed that digital competency (indirect effect = 0.116), human-centric skills (0.103), and sustainable innovation (0.084) all exerted meaningful indirect influences on behaviour through intention. These findings validate the theoretical proposition that competency development must first crystallize into entrepreneurial intention before manifesting as concrete behaviour [21].

Implications for TVET Policy and Practice. The findings suggest a need for integrated curriculum reforms that embed Industry 5.0 competencies within entrepreneurship education [13]. Figure 7 presents a simulation framework illustrating how TVET ecosystems can operationalize these insights.

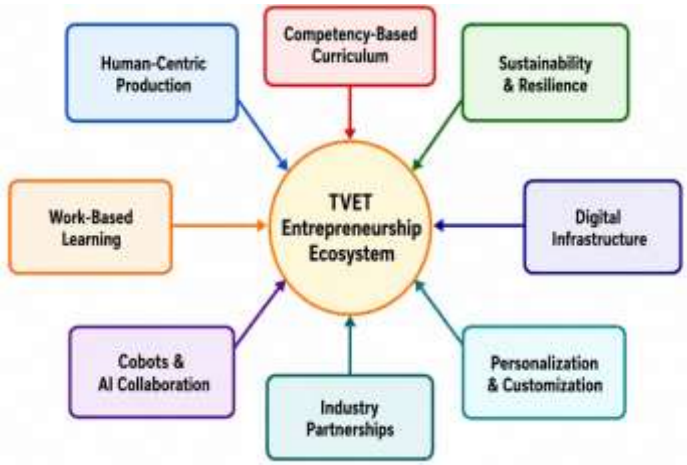

Figure 5. Industry 5.0 simulation framework for TVET entrepreneurship development

4. CONCLUSION

This study provides empirical evidence for the structural relationships between Industry 5.0 competencies and entrepreneurship development in TVET contexts. Through SEM analysis, the research demonstrates that digital competency, human-centric skills, and sustainable innovation are significant antecedents of entrepreneurship intention, which in turn drives entrepreneurship behaviour. Digital competency emerged as the strongest predictor, while sustainable innovation exhibited only indirect effects on behaviour through intention. The model explains substantial variance in both intention (43.4%) and behaviour (48.7%), offering a robust theoretical framework for TVET entrepreneurship education.

The study contributes to the literature by: Operationalizing Industry 5.0 competencies within an entrepreneurship context, validating the mediating mechanism of entrepreneurship intention using CB-SEM, and providing actionable insights for curriculum designers and policy makers in vocational education.

REFERENCES

[1] H.-D. Schreiner, B. Mocan, and M. Fulea, "Adapting Vocational Education for Industry 5.0 by Transforming the Professional Identity of VET Trainers in Wood Processing," in *Innovation, Sustainability, and Growth in a VUCA Environment*, A. L. Negrusa and M. M. Coroş, Eds., Cham: Springer Nature Switzerland, 2026, pp. 67–81. doi: 10.1007/978-3-032-11639-0_5.

[2] A. Arregi Lopez, J. I. Igartua, J. Retegi, J. A. Eguren, and D. Ibarra, "Addressing the challenges associated with Industry 5.0 in higher education: a training concept approach," *TQM J.*, vol. 38, no. 4, pp. 713–731, Aug. 2025, doi: 10.1108/TQM-12-2024-0524.

[3] N. Sterev, R. Miltchev, and D. Yordanov, "Digital Twins as a Bridge Between Industry 5.0 and Education 5.0: Transforming Academic Entrepreneurship and Entrepreneurial Skills," in *Digital Twin Applications and Cognitive Enterprise Transformation Across Industries*, IGI Global Scientific Publishing, 2026, pp. 219–248. doi: 10.4018/979-8-2600-1669-5.ch009.

[4] M. N. Bakkar and A. Kaul, "Education 5.0 Serving Future Skills for Industry 5.0 Era," in *Advanced Research and Real-World Applications of Industry 5.0*, IGI Global Scientific Publishing, 2023, pp. 130–147. doi: 10.4018/978-1-7998-8805-5.ch007.

[5] H. Ho and T. M. Thai, "Education Access Across Sustainability and Industry 5.0: Evidence from Marginalised Youth in Agri-Startups," *Chall. Sustain.*, vol. 14, no. 3, pp. 483–498, May 2026, doi: 10.56578/cis140304.

[6] T. D. Chicioreanu *et al.*, "Education For Industry 5.0: Preparing Higher Education for Sustainable Development and AI Integration Challenges," *J. Fiability Durab.*, vol. 1, pp. 343–359, 2026, doi: 10.65631/jfd.1(37).2026.41.

[7] M. Jogarao, J. Siva Durga Prasad, and P. Sanjeevi, "Empowering the Workforce for Industry 5.0: Skills, Training, and Human-Centric Transformation," in *Building a Human-Centred Infrastructure for Sustainable Industry 5.0 in Asia*, P. Agarwal, N. Kumar, S. Bansal, and Y. Karaca, Eds., Singapore: Springer Nature, 2025, pp. 49–74. doi: 10.1007/978-981-95-0417-6_3.

[8] C. Pacher, M. Woschank, B. M. Zunk, and E. Gruber, "Engineering education 5.0: a systematic literature review on competence-based education in the industrial engineering and management discipline," *Prod. Manuf. Res.*, vol. 12, no. 1, p. 2337224, Dec. 2024, doi: 10.1080/21693277.2024.2337224.

[9] E. Menipaz, N. Bukhshtaber, and B. Bulmash, "Engineering Education for Industry 5.0: A Systemic Approach to AI-Driven Talent Development," in *Proceedings of the International Conference on Industrial Logistics (ICIL) 2025*, U. A. Ozturk and P. T. Helo, Eds., Cham: Springer Nature Switzerland, 2026, pp. 27–36. doi: 10.1007/978-3-032-14489-8_3.

[10] D. Horvat, A. Jäger, and C. M. Lerch, "Fostering innovation by complementing human competences and emerging technologies: an industry 5.0 perspective," *Int. J. Prod. Res.*, vol. 63, no. 3, pp. 1126–1149, Feb. 2025, doi: 10.1080/00207543.2024.2372009.

[11] R. F. Meditama and Mardji, "IMPROVE HIGH ORDER THINKING SKILLS (HOTS) THROUGH VOCATIONAL EDUCATION IN READINESS TO FACE THE 5.0 INDUSTRIAL REVOLUTION," *Int. Semin. Islam. Educ. Peace*, vol. 2, pp. 267–276, 2022.

[12] P. Marinič and P. Pecina, "INDUSTRY 5.0 IN VOCATIONAL EDUCATION," *INTED2023 Proc.*, pp. 3805–3811, 2023, doi: 10.21125/inted.2023.1018.

[13] H. T. Wulandari, H. Susanto, H. J. Prayitno, Indri, B. Wardhana, and F. R. U. Haq, "Integrating Technical Skills, Soft Skills, and Digital Technology in Culinary Vocational Education: A

Deep Learning Model for Industry 5.0," *J. Deep Learn.*, pp. 50–66, Apr. 2026, doi: 10.23917/jdl.v2i1.12927.

[14] A. Jaedun, M. Nurtanto, F. Mutohhari, I. N. Saputro, and N. Kholifah, "Perceptions of vocational school students and teachers on the development of interpersonal skills towards Industry 5.0," *Cogent Educ.*, vol. 11, no. 1, p. 2375184, Dec. 2024, doi: 10.1080/2331186X.2024.2375184.

[15] G. U. Ikenga and P. van der Sijde, "Twenty-First Century Competencies; about Competencies for Industry 5.0 and the Opportunities for Emerging Economies," *Sustainability*, vol. 16, no. 16, p. 7166, Jan. 2024, doi: 10.3390/su16167166.

[16] I. G. Uzoamaka and P. Van Der Sijde, "Twenty-First Century Competencies; About Competencies For Industry 5.0 And The Opportunities For Emerging Economies," Jul. 04, 2024, *Business, Economics and Management*. doi: 10.20944/preprints202407.0429.v1.

[17] O. E. Ajayi and M. Letseka, "From Engagement to Outcomes: AI-Driven Learning Analytics in Higher Education—Insights for South Africa," *Trends High. Educ.*, vol. 5, no. 1, p. 16, Mar. 2026, doi: 10.3390/higheredu5010016.

[18] R. Lampou, M. Noor, R. Vivekanantharasa, and S. Patnaik, "AI–Driven Educational Ecosystems: Integrating Learning Analytics, Adaptive Assessment, and Intelligent Feedback for Sustainable Student Performance," *Qubahan Techno J.*, vol. 5, no. 1, pp. 25–36, Jan. 2026, doi: 10.48161/qtj.v5n1a80.

[19] A. F. Mena Guacas, P.-C. Mellado-Moreno, J.-T. Calderón-Cisneros, and N. Pelicano Piris, "Mapping artificial-intelligence-driven innovation in higher education: A bibliometric review," *Soc. Sci. Humanit. Open*, vol. 13, p. 102561, Jun. 2026, doi: 10.1016/j.ssaho.2026.102561.

[20] H. Sarun, I. Nara, and H. Hun, "The Role of Artificial Intelligence in Transforming Higher Education Quality and Effectiveness: A Nano Review," vol. 3, pp. 32–34, Mar. 2026, doi: 10.5281/zenodo.18264312.

[21] C. Dumitru, G. Muttashar Abdulsahib, O. Ibrahim Khalaf, and A. Bennour, "Integrating artificial intelligence in supporting students with disabilities in higher education: An integrative review," *Technol. Disabil.*, vol. 38, no. 1, pp. 3–24, Feb. 2026, doi: 10.1177/10554181251355428.