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INNOVATIVE APPROACH TO MEASURING MEANINGFUL LEARNING IN DIGITAL TVET

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Abstract: *Digitalization and Industry 4.0 require a shift from traditional assessment methods to more authentic, competency-based evaluations that are aligned with real-world applications. As industry processes evolve through advanced technologies, the need for a new assessment approach in TVET becomes increasingly evident. Traditional assessments, often summative and content-focused, are inadequate in capturing the skills and competencies necessary for students to thrive in modern industries. Authentic assessments, which integrate realistic work tasks, collaborative problem-solving, and cognitive complexity, offer a more relevant means of assessing student learning. These assessments enable students to demonstrate their technical skills in contexts that mirror workplace challenges, while also showcasing competencies that reflect their learning journey. This approach not only aligns with industry standards but also fosters critical thinking, innovation, and engagement. Supported by evidence-based expert recommendations, this study explores innovative approaches to enhance TVET quality, ensuring the development of Industry 4.0-ready talents. The study gathered insights from nine experts for the Nominal Group Technique (NGT) and Interpretive Structural Modelling (ISM), and each expert with over ten years of experience in mechanical and manufacturing-related diploma programmes from both public and private TVET institutes in Malaysia. These experts bring a wealth of diverse perspectives from portfolios that include curriculum development, assessment, media, industry advisory, teacher training, and management. The findings revealed three prioritized strategies to be adopted: 1) Authentic and Task-Specific Assessments, 2) Process and Procedural Evaluation, and 3) Criterion-Referenced and Rubrics-Based Assessments. By adopting these strategies, TVET institutions can more effectively evaluate students' competencies in ways that mirror the dynamic and evolving demands of the world of work. This article provides actionable strategies and insights for educational leaders and instructors, offering an innovative approach to align assessment practices with the evolving needs of technology-driven industries.*

Keywords: *TVET, Competency-based assessment, Industry 4.0, Digitalisation, NGT, ISM.*

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Introduction

The landscape of Technical and Vocational Education and Training (TVET) is undergoing rapid transformation, driven by the convergence of technological advancements, digitalization, and global crises such as the COVID-19 pandemic. As industries worldwide evolve with the integration of Industry 4.0 technologies, TVET systems are faced with the imperative to rethink their evaluation strategies. The global shift toward digitalization, automation, and artificial intelligence is reshaping not only industries but also the skills and competencies required of workers. As a result, TVET assessments, traditionally based on theoretical exams and practical evaluations, are increasingly inadequate in capturing the diverse skill sets needed for the modern workforce (Stolte, 2021; Spöttl et al., 2021).

Industry 4.0, which emphasizes smart manufacturing, interconnected systems, and automation, is introducing new challenges for TVET institutions. The rapid pace of technological change means that graduates must possess not only technical proficiency but also the cognitive and problem-solving skills necessary to adapt to evolving work environments (Björkdahl, 2020). Traditional assessment methods, primarily summative and theory-based, fail to adequately evaluate critical competencies such as adaptability, collaboration, and the ability to use digital tools effectively. This disconnects between TVET assessments, and the real-world demands of the workplace has become more pronounced as industries move toward digitized, data-driven models of production and services (Schröder, 2019; Acemoglu & Restrepo, 2018).

The COVID-19 pandemic has further highlighted the inadequacies of traditional TVET evaluation methods. As educational institutions worldwide shifted to remote learning, TVET providers faced significant challenges in maintaining the quality and integrity of their assessments (Shay & Pohan, 2021). The need for hands-on, practical training, which is core to TVET, was severely impacted by lockdowns and social distancing measures. The disruption forced many institutions to rapidly adopt digital tools and online platforms to continue the learning and assessment process. However, this transition exposed existing gaps in digital infrastructure, instructor preparedness, and student access to technology. In many regions, including Malaysia, these barriers significantly hindered the ability to provide assessments that truly reflected the competencies required for the modern workforce (Ghavifekr et al., 2016; Chuah & Mohamad, 2020).

Moreover, the COVID-19 crisis underscored the urgency of preparing TVET learners for a future shaped by continuous technological change. As industries struggle to adapt to new work paradigms, the skill gap continues to widen, particularly in fields such as data science, automation, and cybersecurity (Ismail & Hassan, 2019). In Malaysia, the shift towards a digital economy has accelerated the demand for a workforce that can effectively leverage advanced technologies. However, TVET institutions often struggle to keep pace with this demand, as their traditional assessment frameworks remain rooted in outdated methodologies that fail to capture the breadth of skills needed in the digital age (MBOT, 2021).

Globally, the call for competency-based assessments in TVET has grown louder. Rather than focusing solely on academic knowledge, assessment practices are shifting towards measuring practical, real-world skills that can be directly applied in the workplace (Spöttl, 2020). Authentic assessments, which simulate real-life work scenarios, are increasingly seen as an effective way to evaluate learners' preparedness for the challenges they will face on the job. These assessments allow students to demonstrate their ability to solve complex problems, work collaboratively, and apply their knowledge in dynamic, technology-driven environments. However, the adoption of such methods requires significant changes to existing TVET systems,

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including curriculum redesign, instructor training, and investment in digital infrastructure (Stolte, 2021; UNESCO, 2003).

As industries worldwide continue to embrace digital technologies, TVET institutions requires a shift in their approaches to integrate industry needs and real-world applications to both teaching and assessment (Raihan Tahir & Zuraidah Abdullah, 2024) . The goal is not only to ensure that students acquire technical expertise but also that they develop the critical thinking, creativity, and adaptability needed to thrive in a rapidly changing world (Tucker, 2021). TVET evaluations must evolve to reflect the competencies required in the workplace of the future. This transformation is not merely about updating content or methods but about rethinking the very nature of assessment—moving from traditional, theoretical measures to more dynamic, real-world evaluations that mirror the complexities of the modern workforce (Spöttl et al., 2021; Acemoglu & Restrepo, 2018).

Problem Statement

The shift towards digitalisation in the Learning and Teaching (L&T) process within TVET institutions, driven by both national initiatives and global phenomena such as Industry 4.0 and the COVID-19 pandemic, has underscored a critical need to reassess and redesign evaluation frameworks in TVET (ILO, 2020; EPU, 2021). In Malaysia, government strategies, including the Digital TVET initiatives, seek to modernise TVET systems to meet the demands of the digital economy. However, despite these efforts, there remain significant challenges in adapting evaluation practices to align with the digital transformation of TVET. Traditional assessment methods, such as written exams and summative tests, no longer adequately measure the competencies required in digitalised and technology-driven work environments (Azmanirah et al., 2014). These conventional methods fail to address essential skills like problem-solving, adaptability, collaboration, and digital literacy, which are integral to the current and future workforce (Juhary, 2020; Spöttl, 2020).

The COVID-19 pandemic accelerated the transition to online and remote learning, exposing the limitations of traditional assessment models, including issues related to validity, fairness, and the authenticity of assessments conducted in a digital format (Alessio et al., 2017; Whittle et al., 2020). As TVET institutions rapidly adapted to emergency remote learning strategies, new evaluation challenges arose, such as ensuring the reliability of assessments conducted through online proctoring tools and measuring practical skills in a remote environment (Escobar & Morrison, 2020; Sumardi & Nugrahani, 2020). The pandemic highlighted the need for assessment systems that can authentically evaluate the competencies needed for Industry 4.0, particularly in fields that require hands-on practice and real-time problem-solving (Carter et al., 2020). However, these shifts have also exposed a digital divide, particularly in terms of instructors' technological competence and access to digital infrastructure, which further complicates the transition to modern assessment practices (Gan & Sun, 2021; Juhdi et al., 2010). Furthermore, the growing emphasis on Industry 4.0 has led to a demand for an updated competency-based approach to evaluation in TVET, which focuses on real-world application of skills rather than theoretical knowledge alone. Traditional assessments have proven inadequate in capturing this shift. TVET institutions must embrace more dynamic, authentic, and competency-based evaluation methods that mirror real workplace scenarios (Spöttl et al., 2021). However, as many TVET institutions struggle with the integration of technology and the development of digital pedagogical skills among instructors, a critical gap exists in ensuring that evaluation practices are aligned with both technological advancements and industry needs (Ibrahim et al., 2018; Azman & Ibrahim, 2018).

The lack of robust digital assessment methods that reflect the needs of the modern workforce has created a disconnect between what is taught in TVET institutions and what is expected in the workplace. Current evaluation methods fail to measure critical competencies such as digital literacy, technical proficiency, and higher-order thinking, which are essential in the digital economy (Bezuidenhout, 2018; Liu et al., 2020). This misalignment has been exacerbated by the inadequate preparation of technical TVET instructors in digital pedagogies and assessment techniques (Shafei et al., 2018). As such, there is an urgent need to reform the evaluation models within TVET to better align them with the evolving demands of industry and the digital economy, particularly in terms of integrating new assessment strategies that promote practical, hands-on learning and allow for the dynamic evaluation of competencies (Spöttl & Windelband, 2021; Ivaldi et al., 2021).

In response to these challenges, there is a clear need for the development of comprehensive, industry-relevant, and technology-infused evaluation frameworks that not only measure knowledge but also the practical application of skills in real-world scenarios. By aligning evaluation methods with digitalisation and Industry 4.0, TVET institutions can ensure that graduates possess the competencies necessary to succeed in the rapidly evolving workforce. As the landscape of education continues to shift towards digital and blended learning models, it is critical to develop evaluation practices that support the changing nature of education and address the emerging challenges within TVET systems. These reforms are essential not only for improving the quality of assessment but also for enhancing the overall effectiveness of TVET programmes in preparing students for the demands of the modern, digital economy.

Research Objective

To explore innovative strategies for measuring meaningful learning in Digital TVET, that align with the dynamic needs of Industry 4.0 and digital transformation in education and training.

Research Questions

The guiding research questions are as follows:
RQ 1 What are the proposed strategies according to experts' consensus to effectively innovative approach to measuring meaningful learning in Digital TVET?
RQ 2 Which of the proposed strategies according to TVET experts' consensus, should be prioritised to effectively innovative approach to measuring meaningful learning in Digital TVET?

Literature Review

The shift towards Industry 4.0 and digitalisation necessitates a reassessment of traditional summative evaluation methods, as industries increasingly demand higher-order skills and real-world competencies. This section reviews key literature on innovative assessment approaches in TVET, in developing more effective assessment frameworks for measuring meaningful learning in Digital TVET.

Competency based assessment

Competency-Based Assessment (CBA) focuses on evaluating learners' ability to apply knowledge, skills, and attitudes in real-world contexts rather than relying on traditional time-bound or norm-referenced evaluations (Hodge, 2007). Unlike summative assessments, CBA emphasizes mastery, allowing learners to progress based on demonstrated competencies rather than standardized testing. Scholars such as Elam (1971) and Yusop et al. (2022) highlight the effectiveness of CBA in aligning education with industry requirements, ensuring graduates are job-ready. This section explores the principles, benefits, and challenges of CBA, particularly in the context of Digital TVET and Industry 4.0. Characteristics of CBA in assessing student learning in Malaysia as gazetted by Malaysian Qualifications Agency (MQA), 2020 are described in Table 1 below. It gives significant attention to learner competency in meeting job competency standards.

Table 1: Characteristics of Competency-Based Assessment

Characteristics
• standards of job competency • include criteria of a good job • assessment is individual, with no comparison among candidates. • judgement on candidate competency • tool for orientation of subsequent learning • basis for the certification of job competency • includes Recognition of Prior Achievement (RPA)

Source: Malaysian Qualifications Agency. (2020). *Code of Practice for TVET Programme Accreditation (COPTPA)* 2nd Edition.

There are theoretical components and practical components to be assessed in TVET. CBC assessments are often authentic and performance-based, evaluating students' ability to apply knowledge and skills in real-world contexts. Theoretical and practical components are generally assessed using written, oral, or practical tests. It may involve demonstrations, projects, portfolios, or simulations. Instead of traditional grades reflecting a pass, CBC often utilizes competency-based transcripts that provide a comprehensive view of student mastery of specific competencies. The criterion-referenced performance measurement is transformed into a procedure for determining whether a student is ‘competent’ or ‘not yet competent’ (Hodge, 2007).

Theoretical and practical assessment

Assessments in TVET are conducted in designated facilities and adhere to established procedures, encompassing both formative and summative components. Theoretical assessments include written and oral tests, with selection-type items offering predetermined answers and supply-type items requiring subjective, examiner-marked responses guided by marking schemes. Practical assessments are performance-based, evaluating tasks such as equipment use, processes, safety compliance, and outcomes, with each component assigned specific weightage. These assessments are authentic, focusing on real-world applications, and passing signifies mastery of course outcomes. However, students generally lack opportunities to defend their answers in both theoretical and practical assessments.

Yusop et al. (2022) emphasized a strong need for well-defined assessment criteria and rubrics in TVET programmes to ensure clear guidelines for evaluating student performance. The scholars added that the current assessment methods might not effectively capture the knowledge and practical skills necessary for real-life tasks and projects. Instead, performance-based assessments, projects, portfolios, and feedback were crucial evaluation components in TVET.

Authentic Assessment

In Malaysia, TVET assessments typically allocate 60% to continuous assessment and 40% to final examination (Azmanirah et al., 2014). Traditional assessments in TVET are summative, content-focused, and norm-referenced, aiming to measure whether students achieve predefined objectives. However, they lack context, limit student involvement, and have rigid scoring systems, diverging from the authentic assessment dimensions described by Frey et al. (2012).

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Authentic assessments, which are more suitable for competence-based curricula, emphasize real-world tasks, enabling students to effectively showcase their competencies (Chu et al., 2018; Frey et al., 2012). The dimension of authentic assessment is shown in Table 2 below.

Table2: Dimensions of Authentic Assessment

Context	Role Of The Student	Scoring
Realistic activity or context	A defence of the answer or product is required.	The scoring criteria are known or student-developed.
The task is performance-based	The assessment is formative.	Multiple indicators or portfolios are used for scoring.
The task is cognitively complex	Students collaborate with each other or with the teacher.	The performance expectation is mastery.

Source: Adapted from Frey et al. (2012)

Authentic assessment evolves from realistic, industry-relevant tasks to cognitively complex challenges, aligning with the goal of fostering 'competence quality' (Spöttl, 2020). Assessments should be realistic and aligned with industry standards, allowing students to justify their answers and build learning through instructor-designed activities. As students perform these tasks, they deepen their understanding, which can be documented in a portfolio—preferably digital in the era of digital transformation. Collaboration is integral, with students sharing ideas to solve complex problems. From a constructivist perspective, meaningful learning happens when students actively solve problems and engage with their environment.

Technology and Assessment

Assessments in TVET institutions are typically conducted on-site, with invigilators overseeing the process. However, moving assessments online presents challenges, particularly in maintaining integrity. Proctoring software has been introduced as a solution, especially for theoretical courses, offering electronic alternatives to human proctoring (Alessio et al., 2017). While video monitoring supports integrity, it has been criticized for causing student anxiety and negatively impacting performance (Daffin & Jones, 2018; Tippins, 2009; Woldeab & Brothen, 2019; Wuthisatian, 2020).

Daffin and Jones (2018) note that both proctored and un-proctored online testing face challenges in ensuring fairness and validity. To address this, some Malaysian engineering programmes have adopted project-based assessments, aligning with authentic assessment principles (Frey et al., 2012). These methods focus on real-world, performance-based tasks that encourage students to justify their answers and demonstrate learning outcomes. Unlike traditional assessments, they emphasize critical thinking, logical reasoning, and meaningful learning (Daffin & Jones, 2018; Sumardi & Nugrahani, 2021). This approach supports the Learning & Teaching (L&T) model by fostering competencies and higher-order thinking skills.

Methodology

Two key research questions guided this study in identifying proposed ideas based on expert consensus and determining which should be prioritized for effective implementation. Nine TVET experts, each with over ten years of experience in manufacturing and mechanical-related diploma programs, contributed their expertise in assessment, management, curriculum development, and innovation. The Nominal Group Technique (NGT) was employed to generate a comprehensive list of proposed ideas, while Interpretive Structural Modelling (ISM) was used to prioritize them. The use of NGT and ISM has been recognized as an effective methodology

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for structuring the TVET curriculum and optimizing learning strategies (Raihan Tahir & Zuraidah Abdullah, 2023). The prioritized ideas from this study will serve as a recommended framework to enhance the organization of Learning and Teaching (L&T) practices in Digital TVET.

Nominal Group Technique (NGT)

The Nominal Group Technique (NGT) is a structured method for identifying a group's shared views on a topic. Many scholars have used it in their research. NGT helps gather collective opinions and insights on specific subjects (Potter et al., 2004; Harvey & Holmes, 2012). Its versatility spans various fields, including education & training (Raihan Tahir & Zuraidah Abdullah, 2024), mental health (Mahmud & Mustapha, 2022; Mustapha et al., 2022), heat energy (Rade et al., 2017), submarine operations (Moelyanto et al., 2021), and safety management (Khan et al., 2017).

Developed in the 1960s, NGT was initially designed for structured group discussions to generate solutions to specific problems (Potter et al., 2004; Harvey & Holmes, 2012). Over time, it gained popularity in fields like consumer research, healthcare, medical sciences, and social work. Researchers favour NGT because it is cost-effective and efficient (Potter et al., 2004).

One of its key strengths is ensuring that all participants contribute ideas and opinions, making discussions more inclusive (Wiggins et al., 2020; Harvey & Holmes, 2012). This structured approach allows for a thorough exploration of topics, helping researchers and professionals address complex issues effectively.

Scholars widely use NGT for data collection due to its efficiency and ease of use. Based on reviewed studies, its benefits include:

1. Ensuring all members have an equal opportunity to share ideas and opinions.
2. Generating a large number of ideas in a short time.
3. Encouraging critical evaluation of each idea's strengths and weaknesses.
4. Making sure every participant's voice from different perspective is heard.
5. Supporting group decision-making.
6. Facilitating effective data collection and meaningful discussions on specific issues.
7. Allowing participants to prioritize and focus on the most important ideas.
8. Being applicable across multiple disciplines.

During the idea generation phase, the appointed facilitator presented the stimulus question to the participants, and they responded individually to each stimulus question and wrote their solutions independently. To prevent a single train of thought, all ideas were recorded and shared with the group. The statements were then collectively reviewed and refined for clarity.
Consensus was reached through voting, using a 5-point Likert scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Not Sure, 4 = Agree, 5 = Strongly Agree. Statements that achieved at least 70% expert consensus, as recommended by Deslandes et al. (2010) and Dobbie et al. (2004), were considered suitable. In this article, the suitable ideas will be used as strategies. The statements were ranked in descending order based on their percentage scores. The NGT process was completed on schedule, ensuring that decisions were made thoughtfully rather than rushed.
This makes NGT a valuable tool for researchers and professionals seeking structured, inclusive, and efficient discussions.

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Interpretive Structural Modelling (ISM)

ISM Concept Star, a licensed software, was used to develop a structured relationship model based on the idea list generated from the NGT process. The ISM methodology follows a systematic approach to analysing and prioritizing strategies through expert input and model generation. This process follows a series of key steps to ensure a logical and data-driven strategy framework.

1. Create relationship model using the suitable idea statements from NGT as input to the software. Expert vote on the relationship between two suitable idea statements. Each expert voted "yes" or "no" on the relationship between strategy statements based on their professional judgment. The guiding construct was:
   "In managing day-to-day learning and teaching processes, TVET technical instructors face various challenges in selecting assessment approach fit for Industry 4.0. The strategy is to..."
   The relationship phrase used was: "This strategy is more significant than...". The majority vote determined the final relationship structure. After the voting is completed, the ISM software generated a structured model, illustrating the hierarchical relationships among strategies. This model visually mapped how different strategies influence each other, helping to identify key driving and dependent strategies.
2. Create reachability matrix to show the representation of the intricate interconnections between these ideas.
3. Partition the ideas. The ideas were then partitioned into different levels based on their relative influence. Foundational ideas appeared at the lower levels, while dependent ideas requiring support from other actions appeared at the higher levels. This hierarchical structuring clarified the logical progression of implementation.
4. Perform MICMAC analysis. A MICMAC analysis was conducted to classify ideas based on their driving and dependent power into four quadrants. Ideas in each quadrant exhibit the following characteristics:
   Quadrant 1 - Autonomous ideas with low influence and low dependence, minimally connected to the system.
   Quadrant II - Dependent ideas with low driving power but highly influenced by other ideas. Important to note that ideas in this quadrant dependent on ideas in Quadrant IV.
   Quadrant III - Linkage ideas with highly interdependent, both influencing and being influenced. The idea in this quadrant is unstable.
   Quadrant IV - Independent ideas. Ideas in this quadrant have the driving and high influence, serving as key drivers for the overall system. Important to note that ideas in this quadrant drive ideas in Quadrant II.

Findings

The findings from this study are derived from the application of two key methods: the NGT and ISM, complemented by MICMAC analysis. The following section presents the output from both methods, highlighting their contributions to instructors upskilling, reskilling and cross skilling strategies for the organisation of learning and teaching in Digital TVET.

Nominal Group Technique (NGT)

Experts ranked all ideas by voting on the generated idea statements. According to Deslandes et al. (2010) and Dobbie et al. (2004), idea statements with 70% or more expert agreement are considered suitable for the next stage. No idea statement received less than 70% agreement, meaning that all ideas were deemed suitable. The output of the NGT process is a list of 10 suitable idea statements. **Error! Reference source not found.** below displays these idea

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statements, numbered in no particular order, along with their respective scores, rank priority, and the percentage of expert consensus.

Table 3: Expert Consensus on Idea Statements

Idea	Statement	Percentage of Vote	Rank Priority	Expert Consensus
10	Create authentic task and align with the learning outcomes and task outcomes (product, process or services) to be achieved.	98	1	Suitable
1	Perform online evaluation for practical (real-time or recorded when the performance criteria are to assess certain procedures or processes).	96	2	Suitable
8	Create real task assignments to assess higher cognitive ability, organisation of work performance-based task.	96	2	Suitable
6	Include open ended questions and application type questions in exam content.	94	3	Suitable
7	Create digital portfolio.	94	3	Suitable
2	Apply hybrid that is focusing on application of theory IN practical assessment. Not separate as theory assessment and practical assessment.	92	4	Suitable
9	Provide content and context specific performance criteria, with multiple indicators, use of rubrics and criterion reference.	88	5	Suitable
3	Conduct self-evaluation on core competency/context specific competencies/required learning outcome.	86	6	Suitable
5	Conduct trainer evaluation on class effectiveness, which include content, student engagement and involvement.	86	6	Suitable
4	Conduct peer evaluation on generic or broad competency (time management, leadership, personal and social skills).	82	7	Suitable

Source: Raihan Tahir. (2024). *Development of I-CODE Model for Technical Instructors in Managing Learning and Teaching Process Towards Digital TVET* (Unpublished Doctoral Dissertation). University of Malaya.

Interpretive Structural Modelling (ISM)

The suitable idea statements are used as inputs in the ISM model. Developing a relationship model manually can be a lengthy and time-consuming process. However, the ISM Concept Star software simplifies this task by automatically identifying the relationships among the various ideas. It efficiently determines which ideas influence or drive the behaviour of the system under analysis. Additionally, the relationship model reveals the driving and dependent powers associated with each idea.

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Relationship Model

The organizational ideas relationship model is shown in Figure 1 below. The directional arrows in Figure 1 indicate the driving factor, following the logical principle that if element A drives element B, and element B drives element C, then it can be inferred that element A drives element C. However, this logic does not hold in reverse. Element C depends on element B, and element B, in turn, depends on element A. Specifically, in **Error! Reference source not found.**, Idea 2 drives Idea 8, and Idea 8 drives Idea 9. It can be concluded that Idea 2 drives Idea 9. However, the logic is not true otherwise. Idea 9 is dependent on Idea 8, and Idea 8 is dependent on Idea 2. The idea on the same level also drives each other. There is no idea on the same level. This relationship model is linear, with Idea 7 having no driving power and dependent on all the previous ideas.

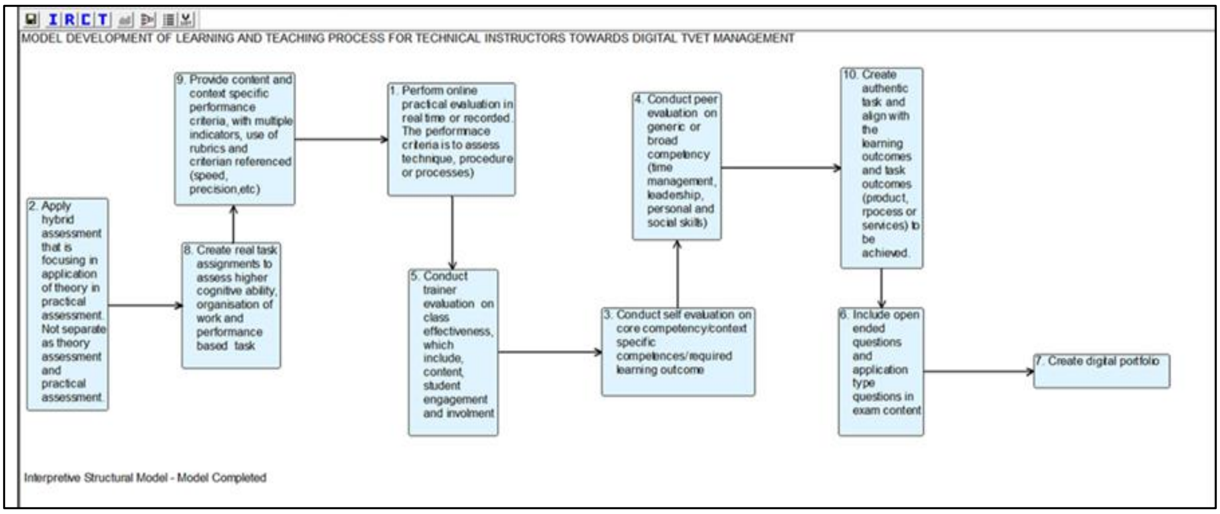

Figure 1: Relationship Model

Source: Raihan Tahir. (2024). *Development Of I-CODE Model For Technical Instructors In Managing Learning And Teaching Process Towards Digital TVET* (Unpublished Doctoral Dissertation). University of Malaya.

Reachability Matrix

To provide a visual representation of the intricate interconnections between these strategies, a reachability matrix is generated. **Error! Reference source not found.Error! Reference source not found.** displays this matrix, and it is derived directly from the relationship model. The values "0" and "1" are derived from Figure 1 using the following rule. "i" and "j" are the strategies. “i” and “j” are the ideas representing the driving power and the dependent power.

Input (i, i) is marked as "1" because i drives itself
Input (i,j) is marked as "1", because i drive j
Input (j, i) is marked as "0" because i is not driven by j.
Input (j,j) is marked as "1", because j drives itself

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Table 4: Reachability Matrix

Idea	1	2	3	4	5	6	7	8	9	10	Driving Power
1	1	0	1	1	1	1	1	0	0	1	7
2	1	1	1	1	1	1	1	1	1	1	10
3	0	0	1	1	0	1	1	0	0	1	5
4	0	0	0	1	0	1	1	0	0	1	4
5	0	0	1	1	1	1	1	0	0	1	6
6	0	0	0	0	0	1	1	0	0	0	2
7	0	0	0	0	0	0	1	0	0	0	1
8	1	0	1	1	1	1	1	1	1	1	9
9	1	0	1	1	1	1	1	0	1	1	8
10	0	0	0	0	0	1	1	0	0	1	3
Dependent Power	4	1	6	7	5	9	10	2	3	8	

Source: Raihan Tahir. (2024). *Development Of I-CODE Model For Technical Instructors In Managing Learning And Teaching Process Towards Digital TVET* (Unpublished Doctoral Dissertation). University of Malaya.

Partitioning

Partitioning or levelling involves categorizing the set of ideas into different levels based on their degree of dependence on one another. The ideas are organized in descending order to establish their hierarchy of importance as shown in Table 5 below. The most influential ideas, which exert the greatest impact, are placed at the top of the hierarchy. The ideas for the organizational dimension have been partitioned into 10 levels. The partitioning process moves from the highest to the lowest level with Idea 2 positioned at Level 10. At the lowest or first level, Idea 7.

Table 5: Partitioning

Idea	Characteristics	Level
2	Create a hybrid (theory IN practical) assessment.	10
8	Create real task assignments to assess higher cognitive ability, organisation of work performance-based task.	9
9	Provide content and context specific performance criteria, with multiple indicators, use of rubrics and criterion reference.	8
1	Perform online evaluation for practical (real-time or recorded when the performance criteria are to assess certain procedures or processes).	7
5	Conduct trainer evaluation on class effectiveness, which include content, student engagement and involvement.	6
3	Conduct self-evaluation on core competency/context specific competencies/required learning outcome.	5
4	Conduct peer evaluation on generic or broad competency (time management, leadership, personal and social skills).	4
10	Create authentic task and align with the learning outcomes and task outcomes (product, process or services) to be achieved.	3
6	Include open ended questions and application type questions in exam content.	2
7	Create digital portfolio.	1

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MICMAC Analysis

The purpose of the MICMAC diagram is to analyse the drive power and dependence power of factors (Attri et al., 2013). The MICMAC diagram is obtained by using the values of the x (dependence power) and y (driving power) axes as (x, y) coordinates in a Cartesian graph. The x and y values are identified and presented in Table 3 below.

Table 6: Driving Power and Dependence Power

Idea	1	2	3	4	5	6	7	8	9	10
x	4	1	6	7	5	9	10	2	3	8
y	7	10	5	4	6	2	1	9	8	3

The coordinate is marked by using the idea statement number. By using these values as the Cartesian coordinate points for MICMAC diagram displayed in Figure 2 below. Each quadrant denotes a specific characteristic for the driving and dependent power.

Quadrant 1 - Autonomous ideas with low influence and low dependence, minimally connected to the system. No idea in this quadrant.
Quadrant II - Dependent ideas with low driving power but highly influenced by other ideas. Important to note that ideas in this quadrant dependent on ideas in Quadrant IV. There are four ideas in this quadrant.
Quadrant III - Linkage ideas with highly interdependent, both influencing and being influenced. The idea in this quadrant is unstable. Idea 3 in this quadrant.
Quadrant IV - Independent ideas. Ideas in this quadrant have the driving and high influence, serving as key drivers for the overall system. Important to note that ideas in this quadrant drive ideas in Quadrant II. There are 5 ideas in this Quadrant IV.

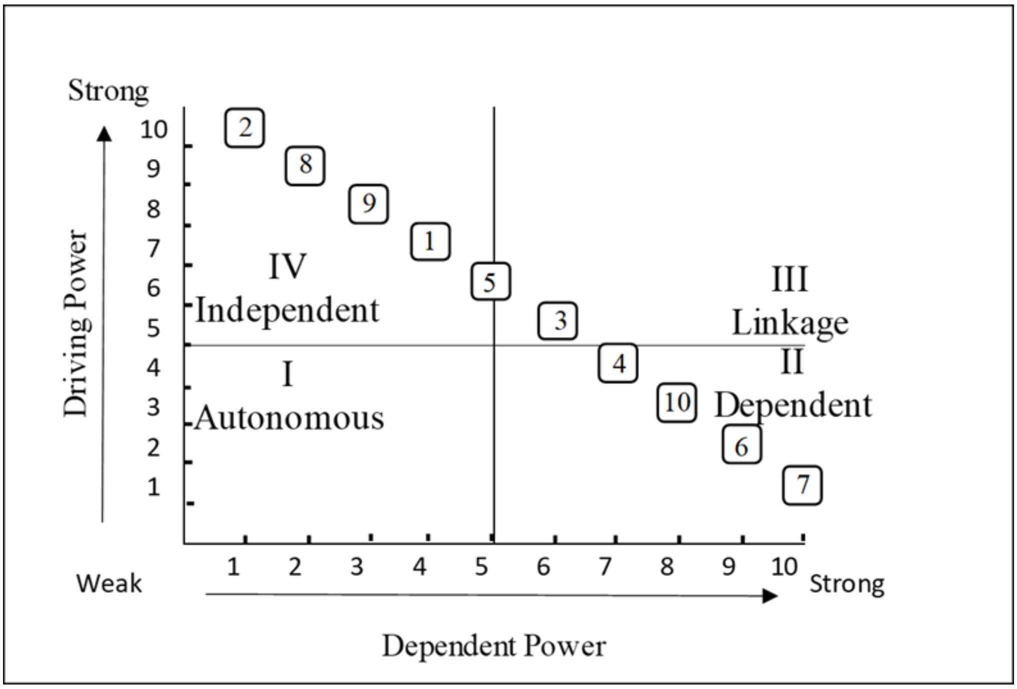

Figure 2: MICMAC Diagram

Source: Raihan Tahir. (2024). *Development Of I-CODE Model For Technical Instructors In Managing Learning And Teaching Process Towards Digital TVET* (Unpublished Doctoral Dissertation). University of Malaya.

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The idea statements from Quadrant IV (independent) and Quadrant II (dependent) of the MICMAC diagram in Figure 2 are presented in Tables 7 and 8, respectively.

Table 7: Independent Idea Statements

Strategy	Statement
Idea 2	Apply hybrid that is focusing on application of theory IN practical assessment
Idea 8	Create real task assignments to assess higher cognitive ability, organisation pf work performance-based task
Idea 9	Provide content and context specific performance criteria, with multiple indicators, use of rubrics and criterion reference
Idea 1	Perform online evaluation for practical (real-time or recorded when the performance criteria are to assess certain procedure or processes)
Idea 5	Conduct trainer evaluation on class effectiveness which include content, student engagement and involvement.

Table 8: Dependent Idea Statements

Strategy	Statement
Idea 4	Conduct peer evaluation on generic or broad competency (time management, leadership, personal and social skills)
Idea 10	Create authentic task and align with the learning outcomes and task outcomes (product, process or services) to be achieved
Idea 6	Include open ended questions and application type questions in exam content
Idea 7	Create digital portfolio

Discussion

The findings highlight the innovative assessment strategies in Digital TVET to ensure meaningful learning and alignment with Industry 4.0 demands. The author derived from the independent statements three central themes; authentic and task-specific assessments, process and procedural relevance, and criterion-referenced and rubrics-based evaluations which offers a practical framework.

Authentic and Task-Specific Assessments

Authentic assessments focus on evaluating learners through real-industry tasks and hands-on experiences. Idea 8 emphasizes the incorporation of real-task projects into the assessment process, enabling learners to demonstrate their competencies in work-like scenarios. Complementing this, hybrid assessments (Idea 2) integrate theoretical knowledge with practical application, fostering a more holistic approach to competency evaluation. These methods allow instructors to measure learners' readiness for the workforce by assessing their ability to apply skills in industry-relevant contexts. Such an approach ensures that assessments reflect real-world challenges, promoting critical thinking and adaptability in students.

Process and Procedural Relevance

Assessing students' understanding and execution of key processes is essential in preparing them for technology-driven industries. Rubrics (Idea 9) provide clear criteria for evaluating learners' performance based on specific procedural requirements, ensuring consistency and transparency in assessments. Additionally, online practical evaluations (Idea 1), conducted in real-time or through recorded sessions, offer scalable solutions for assessing students' ability to execute industry-specific tasks. By integrating structured assessment criteria and digital evaluation

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methods, TVET institutions can ensure students acquire the necessary procedural competencies to navigate modern workplaces effectively.

Criterion-Referenced and Rubrics-Based Evaluations

Ensuring fairness, transparency, and consistency in assessment requires structured evaluation criteria. Rubrics (Idea 9) play a key role in establishing predefined performance benchmarks, ensuring objective assessment of learners' competencies. The evaluation of trainers (Idea 5) further enhances teaching effectiveness by aligning instructional strategies with assessment expectations. Criterion-referenced assessments provide a standardized and industry-aligned framework, ensuring students are evaluated against industry-relevant benchmarks rather than being compared to their peers. This structured approach promotes mastery-based learning, where students progress based on demonstrated competencies rather than time-bound assessments.

The finding also highlights an interplay between dependent and high-driving independent characteristics in shaping effective assessment models. Dependent strategies, such as peer evaluations (Idea 4), problem-centred learning (Idea 10), exam content design (Idea 6), and digital portfolios (Idea 7), highlight the importance of collaboration, curriculum structure, and authentic content. For instance, digital portfolios provide valuable documentation of student work but require high-quality content to be meaningful.

High-Driving Characteristics, such as hybrid assessments (Idea 2), real-task projects (Idea 8), rubrics (Idea 9), online practical evaluations (Idea 1), and trainer evaluations (Idea 5), introduce autonomous and scalable assessment practices. These methods operate independently to enhance assessment validity and instructional effectiveness.

The integration of these two characteristics fosters dynamic, adaptable, and industry-relevant assessments. For example, combining problem-centred approaches with rubric-based evaluations ensures assessments focus on real-world problem-solving while maintaining structured evaluation standards. This synergy results in an assessment framework that is both innovative and aligned with the digital and competency-based demands of TVET.

Conclusion

The findings of this study underscore the urgent need for innovative assessment approaches in Digital TVET to measure meaningful learning effectively. The transition from traditional summative methods to competency-based, authentic, and structured assessments is essential for aligning TVET education with Industry 4.0 demands.

By adopting authentic and task-specific assessments, institutions can ensure that students engage in industry-relevant learning experiences, applying their skills to real-world challenges. Emphasizing process and procedural relevance through structured rubrics and online practical assessments provides transparency and consistency in evaluating learners' technical proficiency and procedural execution. Furthermore, criterion-referenced and rubrics-based approaches reinforce fair, objective, and industry-aligned evaluations, ensuring students meet workforce competency expectations.

The study also highlights the critical interplay between dependent and high-driving assessment characteristics, where elements such as peer evaluations and digital portfolios complement more autonomous methods like hybrid assessments and online evaluations. By strategically integrating these components, TVET institutions can establish comprehensive, flexible, and future-ready assessment models.

To effectively measure meaningful learning in Digital TVET, assessments must be transformed to reflect workplace realities, support higher-order thinking, and provide structured, industry-aligned evaluations. The empirical insights presented in this study serve as a roadmap for reimagining TVET assessment, ensuring that students graduate with the competencies needed to excel in the evolving landscape of digital and technology-driven industries.

We will not have a workforce fit for industry 4.0 and the future world of work if we do not invest to innovate assessment practices in Digital TVET

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