Jurnal Personalia Pelajar 28(1): 165-183
https://doi.org/10.17576/personalia.2801.2025.17
ISSN 0128-2735

Synthesizing Food Services Industry Demands for Fourth Industrial Revolution Skills in Technical and Vocational Education and Training (TVET) Curriculum to Prepare Future-Ready Graduates

(Mensintesis Tuntutan Industri Perkhidmatan Makanan untuk Kemahiran Revolusi Industri Keempat dalam Kurikulum Pendidikan dan Latihan Teknikal dan Vokasional (TVET) untuk Menyediakan Graduan Bersedia Masa Depan)

EVARINA AMIRON & AZLAN ABDUL LATIB

ABSTRACT

This study presents a synthesis of qualitative and quantitative findings on key Fourth Industrial Revolution (4IR) skills for restaurant workers in four Malaysian states which are Penang, Kuala Lumpur, Selangor and Johor. Employing a pragmatic paradigm and a sequential exploratory mixed-methods approach, the research integrated data from restaurant managers, workers, skills trainers, curriculum developers, and academicians. Thematic analysis of interview data in the qualitative phase was followed by a quantitative phase to identify key 4IR skills. Results indicate that risk awareness, operational handling of technology, and communication skills are the most significant skills. Notably, there were differing views between industry practitioners and curriculum developers on the importance of communication skills in the Fourth industrial Revolution contexts. Nonetheless, qualitative insights highlight the critical role of communication skills in the effective use of robots and Internet of Things (IoT) in the Food Services Industry, emphasizing the need for their integration into higher education curricula, such as TVET, to prepare future-ready graduates.

Keywords: Mixed Methods, Fourth Industrial Revolution Skills, Food Services Industry, TVET Curriculum.

ABSTRAK

Kajian ini membentangkan sintesis penemuan kualitatif dan kuantitatif mengenai kemahiran Revolusi Industri Keempat (4IR) utama untuk pekerja restoran di empat negeri Malaysia iaitu Pulau Pinang, Kuala Lumpur, Selangor dan Johor. Menggunakan paradigma pragmatik dan pendekatan kaedah campuran penerokaan berturutan, penyelidikan menyepadukan data daripada pengurus restoran, pekerja, jurulatih kemahiran, pembangunan kurikulum dan ahli akademik. Analisis tematik data temu bual dalam fasa kualitatif diikuti dengan fasa kuantitatif untuk mengenal pasti kemahiran utama. Keputusan menunjukkan bahawa kesedaran risiko, pengendalian operasi teknologi, dan kemahiran komunikasi adalah kemahiran yang signifikan. Terdapat pandangan yang berbeza antara pengamal industri dan pembangunan kurikulum tentang kepentingan kemahiran komunikasi dalam konteks Revolusi Industri Keempat. Namun begitu, pandangan kualitatif menggariskan peranan kritikal kemahiran komunikasi dalam penggunaan teknologi 4IR secara berkesan dalam Industri Perkhidmatan Makanan, menekankan keperluan untuk mengintegrasi kemahiran tersebut dalam kurikulum pendidikan tinggi seperti TVET untuk menyediakan graduan yang bersedia untuk menghadapi masa hadapan.

Kata Kunci: Kaedah Campuran, Kemahiran Revolusi Industri Keempat, Industri Perkhidmatan Makanan, Kurikulum TVET.

INTRODUCTION

The rapid technological advancements of the Fourth Industrial Revolution (4IR) or also known as Industrial Revolution 4.0 (IR4.0) have catalyzed transformative change both economically and socially. As industries face increasing pressure to adopt 4IR technologies, a significant skills gap has emerged within the workforce. Addressing this gap is now essential to achieving organisational goals and promoting sustainable growth (Rikala et al., 2024). In particular, advancements in digitalisation and automation have reshaped the Food Services Industry, especially how restaurant workers interact with customers. Technologies such as robot waiters and Internet of Things (IoT) solutions, which include online menus accessed via Quick Response (QR) codes, have become increasingly common (Kim and Lee, 2020). However, TalentCorp (2021) highlights that many employers have struggled to adopt these digital solutions due to a lack of workforce readiness. This study identifies the main skills required by Food Services Industry workers to be competent in 4IR working environments.

4IR is one of the industrial revolutions that has been widely discussed since its inception by the German government in 2011 (Hermann, Pentek, & Otto, 2016). Notable works are such as by Klaus Schwab (Schwab, K., 2016) and World Economic Forum reports in 2016 and 2020 (World Economic Forum, 2016; World Economic Forum, 2020). There are a plethora of studies on 4IR looking through the lens of various aspects such as 4IR readiness, acceptance or adoption of 4IR-related technologies and solutions, and the impacts of 4IR on the workforce (Spöttl, G., 2016; Spöttl, G. & Windelband, L., 2021).

This study in particular looked into the skills required by Food Services industry workers in restaurants using 4IR technologies,which include the operation of the robots and use of QR, risk awareness, communication skills, training of other staff on how to use the robots and QR codes and collaborative skills. Previous studies mainly focused on the use of 4IR technologies or solutions in industries such as manufacturing, construction, finance, education, and ICT and mostly studied consumers of the technology. Therefore, studies should expand to include other industries and groups or technology users such as workers. The Food & Beverages Industry or also known as the Food Services Industry, is operationally defined in this study as a sub-sector of the Food & Beverages Industry involved in food services such as at dine-in restaurants.

This study focuses on the workers of the Food Services Industry because it is one of the industries that managed to be resilient by moving towards digitisation using 4IR technologies in the restaurants. These technologies include Robotics (i.e. robots serving food in quarantine centres and food outlets) and the Internet of Things (i.e. contactless ordering of food and online payment) (Academy of Sciences Malaysia (ASM), 2020; Santiago, J., Borges-Tiago, M. T., & Tiago, F., 2024) . However other technologies such as Big Data Analytics (i.e. stores customer data and predicts preference in online food and beverage purchase), Blockchain and Cybersecurity (i.e. e- commerce and customer data) have also been applied in the Food Services Industry Studies on skills gaps such as the review by Rikala, P., Braun, G., Järvinen, M., Stahre, J., & Hämäläinen, R. (2024) highlighted that skill gaps should collectively be from the view of education providers, employees, and employers. Furthermore, previous literature reviews have mainly analysed the organizational and labour market levels, with only a few considering the view of individual employees. Based on this insight, this study analysed the required 4IR skills from the perspective of managers, business owners or management-level staff, workers, education providers and curriculum developers.

Due to the technological advancements of cyber-physical systems brought forth by 4IR, the workforce has to be equipped with suitable skills when utilising 4IR technologies. Subsequent research has discussed the impacts of 4IR on the working world (Spöttl, G., 2015; Tūtlys and Spöttl, G.,2021). These skills are defined in this study as 4IR skills. Previous research has highlighted that emerging skills required when using 4IR technologies must be embedded in tertiary-level education curricula (Jeganathan et al.,2019; Lensing & Friedhoff, 2018; Schallock et al., 2018; Spöttl,G., 2015; Wermann et al., 2019). Tūtlys and Spöttl (2021)'s research suggested embedding 4IR-related competencies in the TVET curriculum by updating the skills required when utilizing these technologies. The reason that these skills are mapped to industry requirements is to enable workers to optimise 4IR technologies and solutions geared towards meeting the goals of 4IR implementation in an organization (Amiron, E., Abdul Latib, A.,& Subari, K., 2019; Amiron, E.,2020).

Impact of Evolving Technological Innovations on Skills Demands

The evolution of innovation is often described through the technology life cycle, first conceptualized by Vernon (1966), which outlines five stages: Introduction,

Growth, Maturity, Saturation, and Decline. While the original model provides a foundational understanding, it remains relevant today and has been widely adapted in discussions of digital and industrial innovation (Huang, J., 2025; İlkay and Bilgili, 2025). At the Decline stage, existing innovations may be replaced by newer ones. Fourth Industrial Revolution (4IR) technologies, such as the Internet of Things (IoT), Cybersecurity, Cloud Computing, Blockchain, Automation and advanced robotics, Artificial Intelligence (AI), and Big Data Analytics, are currently at the Maturity stage. These core advancements are widely integrated across industries, remain highly competitive, and continue to evolve through cross-functional applications in sectors like agriculture, energy, water, manufacturing, logistics, and banking.

Meanwhile, some innovations like Augmented Reality (AR), Virtual Reality (VR), 3D printing, and Advanced Materials are in the Growth phase, whereas neurotechnology and biosciences are still emerging, positioned at the Introduction stage. Recognising these stages helps explain why certain tools are more commonly adopted than others, and highlights that mature systems may soon approach saturation. As with mobile phones, which are now essential in daily life, saturated digital systems may become abundant across all sectors of society.

This projected shift highlights the urgent need to equip the workforce with the relevant competencies to use these systems effectively. A skilled workforce is essential for optimising the full potential of 4IR-driven environments. In this study, 4IR skills are operationally defined as the abilities required by workers to effectively apply 4IR-related innovations in their respective professional settings (Amiron, E., 2020; Saari, A., 2021).

To effectively impart the necessary skills for utilizing 4IR technologies would be via Technical and Vocational Education and Training (TVET). TVET is advantageous because it draws on the expertise of industry professionals and practitioners. It proves to be cost-effective and efficient for training both future and current workers due to its curriculum design, which focuses on competency units. This design allows for shorter training periods and quicker assessment and certification turnaround times. Particularly in time-sensitive situations, aligning the 4IR skills needed in relevant industries with TVET programs is beneficial as trainees are already familiar with their work processes. Additionally, they solely need to acquire knowledge and skills related to utilizing 4IR technologies specific to their industries, which is more effective than learning about a technology in isolation. The principle of transfer of learning conceptualized by Perkins and Salomon (1992), where prior knowledge supports new skill acquisition remains central in skills development literature (Mehner, L., Rothenbusch, S., & Kauffeld, S., 2025; Nur Yunus et al., 2021). Therefore, this research advocates for updating TVET curricula in occupational areas utilizing these technologies to expedite the learning processes in applying these technologies according to specific work environments.

Bridging Between Existing TVET Curriculum and The Evolving Needs of 4IR

The Technical and Vocational Education and Training (TVET) curriculum in Malaysia, known as the National Occupational Skills Standard (NOSS), is developed by the Department of Skills Development (DSD) under the Ministry of Human Resources. The primary data sources for NOSS development are industry practitioners actively engaged in their respective occupations, rather than their superiors or subordinates. The NOSS undergoes a rigorous evaluation and validation process involving industry stakeholders and regulatory bodies before the final endorsement at the Ministry of Human Resources level (DSD, 2020). As a result of this rigorous process, it is subject to be reviewed every 2-5 years based on industry requests or feedback from end-users such as training centers and accredited personnel. Review requests may arise even if the document is less than 5 years old and requires updating due to changes in industry conditions, job scopes, or advancements in technology that affect competencies. However, decisions to review it within a 5-year timeframe are carefully considered due to the associated costs and time required for the review process.

To ensure skills training students are adequately prepared for the current job market, the NOSS must include information on 4IR technologies relevant to their working environment. However, some have yet to incorporate such information. While the NOSS outlines the minimum competencies required for workers in Malaysia, there are occupations where 4IR technologies are increasingly prevalent. Dieppe (2021) stresses the importance for emerging and developing countries to ensure tertiary education institutions provide education and training to adapt to skill requirements associated with new technologies. Similarly, Papanai, R., & Poolkrajang, A. (2023) emphasize that a successful curriculum necessitates collaboration between curriculum developers, skills trainers, academics, government agencies, and industry experts.

This study focuses on non-technical

occupations, as current research primarily addresses 4IR skills in technical fields (Jeganathan, Khan, Raju, & Narayanasamy, 2019). Specifically, it examines the Food Services sector, particularly dine-in restaurants, where workers are increasingly interacting with 4IR technologies such as robot waiters and online menus accessed via QR codes and the Internet of Things. Integrating these tools into daily operations may pose challenges, particularly for frontline service staff with limited digital training. However, when implemented effectively, these technologies can enhance service efficiency, improve customer experience, reduce labour dependency, and support safer, contactless dining environments. Therefore, aligning the TVET curriculum with relevant 4IR skills is crucial to ensure that workers are prepared to operate, manage, and adapt to these innovations. This study solicited input from both industry practitioners and training/academic personnel regarding the specific competencies needed by workers in Food Services settings that are adopting such technologies.

METHODS

Research Design And Paradigm

This study employed a Sequential Exploratory Mixed-Methods design, following the model variant outlined by Creswell and Plano Clark (2023). This approach was chosen due to its continued relevance in guiding complex, multiphase studies, particularly when research aims to explore emerging fields such as 4IR skills in non-technical sectors, which are still underrepresented in current literature. It is especially effective when the qualitative phase is needed to inform the development of a quantitative instrument. In this study, qualitative data provided crucial context for identifying relevant 4IR skill sets among food services workers, particularly in restaurants. These insights were then used to generate valid and context-specific survey items for the subsequent quantitative phase, following Creswell's guidelines (Creswell, 2005; 2007; 2014; 2023).

In the subsequent quantitative phase, the emergent list of 4IR skills within the context of Food Service workers was confirmed by administering surveys to restaurant workers. A follow-up survey was then distributed to trainers, curriculum developers, and academicians to gather their perspectives on the required 4IR skills for Food Service workers and the factors that influenced 4IR skills acquisition. This survey was analyzed using the Fuzzy Delphi Method (FDM). Both phases, qualitative and quantitative, were linked through the development of the survey instrument, which involved rephrasing survey items from previous studies to suit the context of Food Services workers utilizing 4IR technologies, as observed during in-situ interviews with restaurant staff. The survey aimed to quantitatively generalize the findings of the qualitative phase. The results from both surveys in the quantitative phase were then compared to gauge the preferences of workers and trainers/curriculum developers regarding the key 4IR skills and the factors influencing 4IR skills acquisition to include in the 4IR skills framework.

The sample groups varied across study phases. Initially, the qualitative phase involved interviews with managerial-level restaurant staff. Subsequently, the quantitative phase surveyed restaurant workers. Finally, the Fuzzy Delphi Method analyzed responses from TVET curriculum developers, skills trainers, and academicians specializing in food services and 4IR technologies. Creswell and Plano Clark (2007;2023) advocate for diverse participant involvement across study phases to enhance data validity through the triangulation of perspectives. Papanai and Poolkrajang (2023) stress the importance of including industry practitioners in curriculum development to avoid skills mismatch. Thus, this study examines input from varied contributors to inform the update of 4IR skills in TVET curriculum for the Food Services Industry.

In the qualitative phase, 9 interviewees were purposely selected, with the total number guided by Guest et al.'s (2020) method for determining information saturation. Calculations based on base size, run length, and a 5% new information threshold indicated saturation after 8 interviews. The quantitative phase surveyed 93 staff working in restaurants using 4IR technologies in Johor, Selangor, Wilayah Persekutuan, and Penang. The stratified random sampling method was applied based on information from Malaysian agencies identifying active states in 4IR implementation. The subsequent survey was disseminated to 18 purposively sampled experts comprising curriculum developers, trainers, academicians, and restaurant managers, assessing 4IR skills acquired and required, as well as factors influencing skills acquisition. Triangulation of findings from these diverse groups facilitated comprehensive analysis, revealing both confirmatory and conflicting results.

QUALITATIVE PHASE

The qualitative phase involved interviews with managerial-level staff at restaurants utilizing 4IR technologies in their daily operations. These interviews

were conducted on-site, allowing the researcher to directly observe the utilization of 4IR technologies by restaurant workers. Nine interviews were transcribed and subjected to thematic analysis, following the methodology outlined by Guest et al. (2012) and Saldana (2013). According to Saldana (2013), themes are phrases that encapsulate a unit of data and its significance. Two coding cycles were conducted, resulting in the identification of 12 main themes and 48 sub-themes in the second cycle, ensuring a comprehensive representation of key textual elements. NVIVO software facilitated the coding process and the classification of interview transcriptions as Cases, facilitating querying, interpretation, and sense-making. The qualitative phase interviews aimed to explore the utilization of 4IR technologies in restaurants and to identify factors influencing the acquisition of 4IR skills. The list of interview participants and brief information are included below.

IP 1: Interview Participant 1 – 4IR Technology Maintenance Manager for Restaurants

IP 2 : Interview Participant 2 – Restaurant Manager

IP 3 : Interview Participant 3 – Restaurant Manager

IP 4 : Interview Participant 4 – Restaurant Manager

IP 5 : Interview Participant 5 – Franchise Restaurant HR Manager

IP 6 : Interview Participant 6 – Restaurant Owner

IP 7 : Interview Participant 7 – Restaurant Manager

IP 8 : Interview Participant 8 – Restaurant Manager

IP 9 : Interview Participant 9 – Restaurant Owner

QUANTITATIVE PHASE

Drawing from the thematic analysis results of the qualitative phase, the identified themes were integrated into survey items designed to assess the factors influencing 4IR skills acquisition. The quantitative phase involved distributing the survey instrument to restaurant workers, followed by a survey aimed at securing expert consensus on the components of the 4IR skills framework tailored for the Food Services Industry. Subsequently, the survey data was analyzed using IBM SPSS.

Table 1 presents the demographic information of the survey respondents. The 93 respondents were restaurant workers from four states in Malaysia which had a high number of restaurants using 4IR technologies; Johor, Penang, Kuala Lumpur and Selangor. Although the initial population was estimated to be 100 restaurants that utilized 4IR technologies, the numbers decreased as several restaurants ceased to use 4IR technology compared to the earlier fact-finding of restaurants that use robots and the Internet of Things. The reasons for not using the technologies were not disclosed by the restaurant staff due to confidentiality issues.

The sampling applied in the survey was stratified random sampling, where the strata were the states grouped into three zones,which were northern, central and southern zones. Subsequently, the survey respondents from the restaurants were randomly selected. It can be seen that the majority of respondents were in the Central Zone of Malaysia with a percentage of 49.5% of respondents and the lowest frequency was from Penang.

TABLE 1. Demography of survey respondents according to zones

Zone (Comprising Malaysian States)		Frequency	Percent
1	Northern (Penang)	13	14.0
2	Central (Selangor and Wilayah Persekutuan)	46	49.5
3	Southern (Johor)	34	36.6
	Total	93	100.0

Table 2 shows the demography of the survey respondents according to the Operational (Service and Kitchen Staff), Supervisory (Branch Manager) and Management or Owner job positions in the restaurant. Due to the method of random sampling, where the workers are selected at random in the restaurant to answer the survey, there were instances where the restaurant staff would comprise either operational staff,

supervisory-level staff, or managerial-level staff. This is because the restaurants would consist of franchises and also small-scale restaurants that were privately owned. Therefore,there were various levels of workers or staff at the restaurant that would answer the survey. According to Table 2, 57% of the survey respondents were those who were working at the operational level.

TABLE 2. Demography of survey respondents according to Job Positions

Job Position	Frequency	Percent	Valid Percent	Cumulative Percent
Operational (Service and Kitchen Staff)	53	57.0	57.0	57.0
Supervisory (Branch Manager)	33	35.5	35.5	92.5
Management or Owner	7	7.5	7.5	100.0
Total	93	100.0	100.0	

Table 3 presents the demography of survey respondents according to the Job Area they are stationed at. These job areas are the physical areas in the restaurants. Four (4) levels of job positions can be stationed at the different areas of the restaurant, such as the restaurant manager who could be stationed at the cashier area and also the dining area. Table 3 shows that the job areas with the highest percentage of 47.3 % are overall restaurant operations, which include overseeing food preparation and service, maintaining cleanliness and hygiene, ensuring customer satisfaction, and other matters such as payment.

TABLE 3**.** Demography of survey respondents according to Job Area

Job Area	Frequency	Percent	Valid Percent	Cumulative Percent
Cashier Area	10	10.8	10.8	10.8
Services at dining area	35	37.6	37.6	48.4
Kitchen	4	4.3	4.3	52.7
Overall Restaurant Operations	44	47.3	47.3	100.0
Total	93	100.0	100.0	

Table 4 shows that 73.1% of the restaurants surveyed used only Automated Robots in comparison to 26.9% of restaurants that used both Automated Robots and the Internet of Things (QR Code). This study selected restaurants that had robots and other additional technology. Restaurants without robots were not selected for the survey.

TABLE 4. Demography of Restaurants according to 4IR Technologies Used

	Frequency	Percent	Valid Percent	Cumulative Percent
Automated Robots and Internet of Things	25	26.9	26.9	26.9
Automated Robots	68	73.1	73.1	100.0
Total	93	100.0	100.0	

Table 5 shows that the Cronbach's Alpha value calculated from the pilot study was 0.972, indicating a high level of reliability (Cronbach, 1951). The analysis included 38 items, excluding the demographic questions which were already validated in the Content Validity stage. For the Cronbach's Alpha test, only items related to the variables were assessed, resulting in the exclusion of five demographic questions. Although Cronbach'sAlpha values above 0.8 are deemed reliable, values exceeding 0.95 may suggest redundancy (Hulin,

Netemeyer, and Cudeck, 2001). Consequently, certain items were removed to lower the Cronbach's Alpha value, leaving the survey with 26 items and an adjusted Cronbach's Alpha value of 0.962.

TABLE 5. Reliability Statistics

Stage	Cronbach's Alpha Value	N of Items
Cronbach's Alpha Before Omitting Items	.972	38
Cronbach's Alpha After Omitting Items	.962	26

RESULTS

This paper focuses on the second Research Question of the overall study, which is listed below:

i. What are the key Fourth Industrial Revolution (4IR) skills required by workers in the Food Service industry?
ii. What are the key Fourth Industrial Revolution (4IR) skills required according to the job positions (occupational levels) at restaurants in Malaysia?
iii. What are the key Fourth Industrial Revolution (4IR) skills required according to the job areas at the restaurants in Malaysia?
iv. What are the key Fourth Industrial Revolution (4IR) skills required according to the 4IR technologies used at the restaurants in Malaysia?

This research question aims to identify the skills required by Food Services workers when using 4IR technology in restaurants. It was addressed in both the qualitative and quantitative phases to obtain a comprehensive understanding. However, the emphasis is not equally divided; the qualitative phase played a more dominant role in exploring emerging themes and generating insights, while the quantitative phase served to validate and quantify these findings among a broader group of respondents. This approach aligns with the principles of a Sequential Exploratory Mixed-Methods design, where qualitative inquiry drives the development of the quantitative instrument. This Research Question was asked in both qualitative and quantitative phases to obtain a holistic view and is elaborated in the sections below.

Qualitative Phase Findings

The results of the qualitative phase's interviews were analysed using thematic analysis and tabulated in Table 6 below. Table 6 shows the descending rank of 4IR skills for restaurant staff according to the total frequency of mentions by each interview participant in the Total column.

Table 6 shows the key skills of restaurant staff according to the frequency of mentions by each interview participant that the skills required for daily operation of technologies and communication skills were mostly mentioned by the restaurant managers. Following these were technical-issues escalation, training of new staff, and risk assessment. The most-mentioned skill by all the restaurant managers was the skill to operate the robot including operational tasks that are carried out when handling the robot such as cleaning and charging of robots, however, the operation of QR code access to online menus or updating of online menu items were the least-mentioned. Communication skills were also mentioned by all restaurant managers as important skills required to communicate with customers when using 4IR technologies such as robots and QR codes. Being able to carry out robot risk assessment and training new staff to use the technology were mentioned by at least seven interview participants. When it comes to technology use, especially with robots, staff must assess and manage risks such as spills onto robots or customers. Adjusting the robot's speed based on the type of food or drink being carried is essential for successful delivery to designated tables. Monitoring is crucial for detecting malfunctions, and staff need to promptly communicate technical issues to maintenance personnel through direct messaging. This may lead to temporary pauses in robot use until the issues are resolved, typically taking a few days to a week. In the context of online menus accessed via QR codes, communication skills play a vital role. Staff must respond promptly and effectively to customer inquiries, ensuring a positive experience during online ordering. Troubleshooting includes addressing issues like internet connectivity and online menu access, tasks that can be handled by authorized staff. The analysis also revealed that interview participants with more technology experience emphasized the importance of these skills. In areas with stable internet connections

TABLE 6. Skills according to Interview Participants Frequency of mentions

Interview Participant (IP)/Skill	IP1	IP2	IP3	IP4	IP5	IP6	IP7	IP8	IP9	Total
1. Robot operation (e.g. Charging, cleaning, keying in table to send food)	1	1	1	1	1	1	1	1	1	9
2. Communication Skills (e.g. explain about the use of QR Code and use of Robots, addressing customer grievances (issues))	1	1	1	1	1	1	1	1	1	9
3. Technical issues escalation of robot/ online menu (IoT via QR Codes) to maintenance personnel	1	1	1	1	1	1	1	1	0	8
4. Robot Risk Assessment (e.g. spills from hot food, robot speed)	1	1	0	1	1	1	1	0	1	7
5. Train new staff to use technology	1	1	1	1	1	1	1	0	0	7
6. Collaborate between sections	1	1	0	1	1	1	1	0	1	7
7. QR Code operation (e.g. updating of online menu items, updating unavailable items on menu)	0	0	1	1	1	0	1	0	0	4

and tech-savvy customers, the need for assistance with QR codes was reduced.

Training new staff in technology use, covering both robots and online menus, emerged as a critical aspect. The technology was generally considered user-friendly, and training typically occurred within the first week of employment. Existing staff, trained by suppliers or maintenance personnel, then passed on this knowledge to their colleagues. This training covered various aspects, including handling robots and setting parameters such as table assignments, music, and robot speed based on the type of food being carried. The same training approach was applied to the use of QR codes. Collaboration between sections was also ranked the same as training and risk awareness, where it depended on the restaurant setup in terms of the collaboration between restaurant sections when using 4R technology. The skills listed above were then included in the instrument survey. The survey was distributed to restaurants that used 4IR technology to gauge the skills required by the workers and also factors that influenced the adoption and use of the technologies leading to the

acquisition of skills required to use these technologies. The 4IR skills required by job area, job position, and technology used are shown in the quantitative phase findings in the following section.

Quantitative Phase Findings

The quantitative phase findings were used to answer Research Question 2, which is to determine the key 4IR skills among the different groups in the sample of restaurant staff and according to types of 4IR technologies used in the restaurant. The groups are levels of job positions (i.e., managerial, supervisory, and operational), and jobs according to job area (i.e., kitchen, service areas, cashier, and overall restaurant operations).

For the quantitative phase, four (4) hypotheses were formulated based on the above research question as follows:

H0 - There are no differences between the studied groups in terms of the key 4IR skills required by Food Service Industry workers.

H1 – The job position influences the key 4IR skills required by Food Service Industry workers.

H2 - The occupational area influences the key 4IR skills required by Food Service Industry workers.

H3 - The type of technology used influences the key 4IR skills required by Food Service Industry workers.

The normality tests showed that the data was skewed. This is common for social sciences research where scores have a negatively skewed distribution if most scores are at the higher end of the survey's Likert scale anchor values representing levels of agreement. This was reflected in the survey responses of this study, where they showed a high level of agreement with the survey items. Therefore, the non-parametric tests were selected to analyse the data. To analyse the difference of scores between groups in the survey sample, the non-parametric versions of ANOVA and t-test, which are the Kruskal-Wallis Test and Mann-Whitney U test were applied. The null hypothesis could be rejected as there were significant differences between the sample groups.

4IR Skills According To Job Positions

Hypothesis H1 is maintained because the results show that the job position influences the key 4IR skills required by Food Service Industry workers. The first sub-question of the research questions is to identify the 4IR skills according to the groups of job positions, which were at the managerial level, supervisory and operational. This was done by running the Kruskal-Wallis test and comparison of means and medians on the survey data.

TABLE 7. Kruskal-Wallis - Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of total 4IR skills is the same across categories of Job Position Category.	Independent-Samples Kruskal-Wallis Test	.013	Reject the null hypothesis.

The significance level is .050.

Asymptotic significance is displayed.

The Kruskal-Wallis Test results presented in Table 7 and Table 8 show a statistically significant difference in 4IR skills required across three job positions, namely at managerial, supervisory and operational levels, with a p-value of 0.013, which is less than 0.05. Whereas Table 8 can be summarized with the following equation,($\chi 2$ (2, n = 93) = 8.64, p = .013), where x squared with a degree of freedom of 2 and a sample of 93 persons resulted in a chi-square value of 8.64 and a p-value of 0.013.

TABLE 8. Independent-Samples Kruskal-Wallis Test Summary

Total N	93
Test Statistic	8.636[a]
Degree Of Freedom	2
Asymptotic Sig.(2-sided test)	.013

a. The test statistic is adjusted for ties.

Table 9 shows that the p-values for the items, Operational Handling of 4IR Technology (0.48), Collaborate between Sections (0.49), and Communicate with Maintenance Personnel (0.27) were significant because the p-values for the 4IR skills were below $p < 0.05$ when compared between groups of Job Positions.

TABLE 9. Kruskal Wallis Test results for 4IR skills according to Job Position

	Communicate with Customer	Operational Handling of 4IR Technology	Risk Awareness	Need to train new workers how to use robots and QR Code	Collaborate between sections	Communicate with Maintenance Personnel
Kruskal-Wallis H	4.397	9.572	7.097	3.836	9.531	10.926
df	4	4	4	4	4	4
Asymp. Sig.	.355	.048	.131	.429	.049	.027

a. Kruskal Wallis Test

b. Grouping Variable: Job Position

To identify which group of Job Positions have a significant difference, the pairwise comparison of the Job Position categories is referred to. This is shown in Table 10, where the p-value of 0.003 between Operational and Supervisory staff implies a significant difference.

TABLE 10**.** Pairwise Comparisons of Job Position Category

Sample 1-Sample 2	Test Statistic	Std. Error	Std Test Statistics	Sig.	Adj. Sig.[a]
Operational (Server and Kitchen Staff)-Management or Owner	8.721	10.696	.815	.415	1.000
Operational (Server and Kitchen Staff)-Supervisory (Branch Manager)	17.292	5.898	2.932	.003	.010
Management or Owner - Supervisory (Branch Manager)	-8.571	11.068	-.774	.439	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significance (2-sided tests) are displayed. The significance level is .050.

a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 11 shows the median and means of each item for the variable 4IR skills. Each item for the variable 4IR skills in the survey represented a specific skill. The list of skills was identified during the qualitative phase's interviews when the restaurant managers were asked about the skills that were required by workers when using the 4IR technologies at the restaurant. The skill known as "Technical Issue Escalation" in the qualitative phase was reworded to "Communicate With Maintenance Personnel" to simplify the context.

TABLE 11. Median and Mean Comparison of 4IR Skills According To Job Positions

Job Position Category		Communicate with Customer	Operational Handling of 4IR Technology	Risk Awareness	Need to train new workers how to use robots and QR Code	Collaborate between sections	Communicate with Maintenance Personnel
Managerial (Management / Owner)	N	7	7	7	7	7	7
	Median	6.00	6.00	7.00	6.00	6.00	6.00
	Mean	6.00	5.43	5.57	6.00	5.57	5.29
Supervisory (Branch Manager)	N	33	33	33	33	33	33
	Median	6.00	6.00	6.00	6.00	6.00	6.00
	Mean	6.03	5.97	6.06	6.03	6.03	5.91
Operational (Server and Kitchen Staff)	N	53	53	53	53	53	53
	Median	6.00	7.00	6.00	6.00	5.00	5.00
	Mean	5.57	6.06	5.96	5.58	5.34	5.26
Total	N	93	93	93	93	93	93
	Median	6.00	6.00	6.00	6.00	6.00	6.00
	Mean	5.76	5.98	5.97	5.77	5.60	5.49

Table 11 shows that the highest median for Managerial level staff was for the Risk Awareness skill with a median value of 7.00. The median values for 4IR skills required by staff at the Supervisory level were all similar, which was 6.00, therefore the mean value was observed. Based on the mean value, the skill that had the highest value for Supervisory staff at the restaurant was Risk Awareness. Finally, for Operational staff, the skill with the highest median was Operational Handling of 4IR Technology,which had a value of 7.00.

4IR Skills According To Job Areas

The second sub-question of the research question is to identify the 4IR skills according to the groups of Job Areas of the restaurant, which are the cashier area, kitchen, services dining area, and overall restaurant operations. Table 12 shows that the p-value is more than 0.05, therefore there is no significant difference between the 4IR skills across the job areas in the restaurant. When there is no significant difference between these sets of data, it means that there is not enough evidence to conclude that the two sets are truly different. Therefore, hypothesis H2 (The occupational area influences the key 4IR skills required by Food Service Industry workers) is rejected and the null hypothesis is retained. This could be due to a variety of factors such as sample size, or measurement error rather than a true effect on the population. Essentially, it suggests that the observed differences between the two sets are not large enough to be considered meaningful or statistically significant. Therefore the difference between groups of job areas is not further explored in the analysis.

TABLE 12. Kruskal-Wallis - Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of 4IR skills is the same across categories of Job Area.	Independent-Samples Kruskal-Wallis Test	.188	Retain the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Table 13 shows the key 4IR skills according to the job area. Due to the p-value that is not significant for the differences between the job areas, only medians or means that are higher than other skills are observed to gauge the most frequently answered by the survey respondents. In summary, the job areas of Overall Restaurant Operations, Services at the Dining Area, and the skills of Operational Handling of 4IR technology have the highest median and mean values. There are job areas with no significant median or mean of higher values higher than the other skills, which are the Kitchen and Cashier Areas. This may be because the staff in the kitchen area do not frequently use 4IR technology such as robots, except for restaurants where there is a lack of staff and situations where kitchen or service staff set the table numbers for the robots to deliver food and beverages. For the Cashier job area, there are no differences because there are various staff who may work at the cashier such as restaurant managers, supervisors, or servers.

TABLE 13. Median and Mean Comparison of 4IR Skills According To Job Areas

Job Area		Communicate with Customer	Operational Handling of 4IR Technology	Risk Awareness	Need to train new workers how to use robots and QR Code	Collaborate between sections	Communicate with Maintenance Personnel
Overall Restaurant Operations	N	44	44	44	44	44	44
	Median	6.00	7.00	6.50	6.00	6.00	5.50
	Mean	5.86	6.34	6.11	5.86	5.64	5.75
Kitchen	N	4	4	4	4	4	4
	Median	4.00	4.00	4.50	4.50	4.50	4.50
	Mean	4.75	4.00	5.00	5.00	5.00	5.00
Services at dining area	N	35	35	35	35	35	35
	Median	6.00	6.00	6.00	6.00	6.00	6.00
	Mean	5.71	5.66	5.80	5.71	5.74	5.37
Cashier Area	N	10	10	10	10	10	10
	Median	6.00	7.00	7.00	6.00	5.00	5.00
	Mean	5.90	6.30	6.30	5.90	5.20	5.00
Total	N	93	93	93	93	93	93
	Median	6.00	6.00	6.00	6.00	6.00	6.00
	Mean	5.76	5.98	5.97	5.77	5.60	5.49

4IR Skills According To Types of 4IR Technologies

The third sub-question of the research question is to identify the 4IR skills according to the types of 4IR technologies used at the restaurants. Although in the survey a list of seven technologies was included, the responses received indicated the technologies that were mostly used were robots and the Internet of Things (loT), which is used when accessing the online menus via Quick Response (QR) codes. The Mann-Whitney U test was applied to analyse the data because there were only two groups. Table 14 shows that the p-value is less than 0.05, therefore there is a significant difference between the 4IR skills required based on the type of 4IR technologies used in the restaurant. Thus, hypothesis H3 (The type of technology used influences the key 4IR skills required by Food Service Industry workers) is retained.

TABLE 14. Mann-Whitney U Test Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of total 4IR skills is the same across categories of new category 4IR tech.	Independent-Samples Mann-Whitney U Test	.005	Reject the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Table 15 presents the direction of the significance between the groups; thus it can be seen that for restaurants using only Automated Robots, the median is similar for all the 4IR skills, therefore the mean is observed. The highest mean is for the Risk Awareness skill due to the various risks that the robot might face such as the spilling of food and beverages and faulty functionality of the robots, such as not being able to navigate in the restaurant. Whereas for restaurants using both robots and the Internet of Things, a key skill is the Operational Handling f Technology.

TABLE 15. Median and Mean Comparison of 4IR Skills According to Type of 4IR Technologies

4IR Technologies		Communicate with Customer	Operational Handling of 4IR Technology	Risk Awareness	Need to train new workers how to use robots and QR Code	Collaborate between sections	Communicate with Maintenance Personnel
Automated Robots	N	68	68	68	68	68	68
	Median	6.00	6.00	6.00	6.00	6.00	6.00
	Mean	5.97	6.03	6.04	5.97	5.81	5.66
Automated Robots and Internet of Things	N	25	25	25	25	25	25
	Median	5.00	6.00	6.00	5.00	5.00	5.00
	Mean	5.20	5.84	5.76	5.24	5.04	5.04
Total	N	93	93	93	93	93	93
	Median	6.00	6.00	6.00	6.00	6.00	6.00
	Mean	5.76	5.98	5.97	5.77	5.60	5.49

4IR Skills According To The Views Of TVET Curriculum Developers, TVET Institute Trainers, And Industry Trainers

To synthesize the views from industry and trainers/ academia on 4IR skills required by workers in the Food Service industries, a subsequent Fuzzy Delphi Method (FDM) analysis was carried out. This study analysed 15 experts due to the heterogeneous composition of the group consisting of 3 vocational college trainers in food services and preparation, 7 TVET curriculum developers, 5 academicians and industry trainers specializing in 4IR technologies, and 3 restaurant owners/management personnel. The suggested number of expert samples for Fuzzy Delphi Method analysis is between 10-15 (Adler, M., and Ziglio, E., 1996; Izyan Zulkiply, Jaafar, and Faseah Muhamad, 2024; Mohd. Jamil and Mat Noh, 2020).

Analysis on the experts' views was analysed using a pre-formatted Microsoft Excel spreadsheet developed by Mohd Jamil and Mat Noh (2020). The two main prerequisites that must be followed in the Fuzzy Delphi technique are the Triangular Fuzzy Number and the Defuzzification Process. The Triangular Fuzzy Number Threshold (d) value must be less or equivalent to 0.2 ($d \leq 0.2$), the Percentage of Experts' Consensus must be more than 75%, and via the Defuzzification Process, the Fuzzy Score (A) alpha-cut value must be more than 0.5 (Cheng and Lin, 2002; Chu H. C. and Hwang G. J., 2008; Roldán López de Hierro, A. F., Sánchez, M., Puente-Fernández, D., Montoya-Juárez, R., & Roldán, C., 2021; Wan Hamat, W. N., Muhamad, N., Hashim, A., & Mohamed Yusoff, A. F., 2021).

Based on the FDM analysis results in Table 16, the threshold value for Communication skills with customers was 0.313, which is more than the Threshold value of $(d) \leq 0.2$, and the expert consensus was 33% which was lower than the required 75%, thus this item was rejected. However, skills other than Communication with Customers gained consensus more than 75% from experts.

TABLE 16. Fuzzy Delphi Method Results of Key 4IR Skills

Item	Triangular Fuzzy Numbers Condition		Defuzzification Process				Expert Consensus	Acceptance of Element	Ranking
	Threshold d	Expert Consensus	m1	m2	m3	Fuzzy Score (A)			
Communication skills with customers	0.313	33%	0.672	0.817	0.889	0.793	Rejected	-	-
Daily operational handling skills of 4IR technology	0.198	89%	0.783	0.906	0.944	0.878	Accepted	0.878	4
Risk Awareness	0.145	89%	0.756	0.906	0.967	0.876	Accepted	0.876	5
Train new employees how to use 4IR technology	0.088	94%	0.778	0.933	0.994	0.902	Accepted	0.902	1
Communicating the technical problem to maintenance personnel	0.153	94%	0.806	0.928	0.961	0.898	Accepted	0.898	2
Collaboration with other restaurant sections	0.153	94%	0.772	vv0.911	0.961	0.881	Accepted	0.881	3

Condition for Item Acceptance: Triangular Fuzzy Numbers

Threshold Value $(d) \leq 0.2$

Percentage of Experts Consensus > 75% Defuzzification Process

Fuzzy Score $(A) \geq \alpha$ – cut value = 0.5

In terms of ranking, the survey results show that the skill "Train New Employees" ranked first in the list of 4IR skills required at restaurants. This is followed by the skills to Communicate Technical Problems to Maintenance Personnel Collaboration With Other Restaurant Sections, Daily Operational Handling Of Technology, and lastly Risk Awareness.

DISCUSSION

This study aimed to identify and synthesize a list of essential skills required by restaurant workers using Fourth Industrial Revolution (4IR) technologies, based on findings from both qualitative interviews and quantitative surveys. However, after tabulating the lists of skills from the various sources, a discrepancy was apparent. The findings are the result of data triangulation obtained via qualitative and quantitative data collection and analysis. By applying the pragmatic paradigm in the Sequential Exploratory Mixed-Methods research design, instances of discrepancy in the results were overcome by comparing the different analysis results to obtain the final decision.

Table 17 presents the outcomes of this mixed-methods analysis, highlighting that risk awareness, daily operational handling, and communication skills are frequently included in the survey responses across various categories,including job positions, job areas, and types of technology used. These results were determined based on the highest mean and median values according to Job Position, Job Area, and type of technology. The qualitative phase revealed that managerial staff most often emphasized daily system operation and effective communication with customers as crucial competencies. It can be seen that managerial staff would focus more on communicating with customers when technologies are used at the restaurant to assist the customers and ensure a smooth dining experience for them from the point of ordering their meal until the delivery of food and beverages. These skills reflect the frontline realities of maintaining seamless service while integrating technology into customer interactions. In contrast, the quantitative phase ranked risk awareness as the most important skill, especially among supervisory and managerial roles. This includes handling technology-related challenges such as food spillage from robot waiters or connectivity issues with IoT-enabled QR code menus. Operational staff, meanwhile, placed higher importance on the ability to handle these systems in daily tasks. From a technology-specific perspective, robots required more attention to risk awareness, while both IoT and robotic systems demanded strong operational competencies.

TABLE 17. Synthesized Findings from the Qualitative and Quantitative Phase

Qualitative Phase Findings (Interviews with Restaurant managerial staff)	Quantitative Phase Findings (Survey with Restaurant Workers)		
4IR Skills	4IR Skills According to Job Position	4IR Skills According to Job Area	4IR Skills According to 4IR Technology
1. Daily Operational Handling 2. Communication Skills	Managerial Staff 1. Risk Awareness Supervisory Staff 1. Risk Awareness Operational Staff 1. Daily Operational Handling of 4IR Technology	Overall Restaurant Operations 1. Daily Operational Handling Services at dining area 1. Daily Operational Handling	Automated Robots 1. Risk Awareness IoT and Robots 1. vDaily Operational Handling

When synthesizing the analysis findings, it becomes evident from Table 18 that there is a discrepancy in the lists and rankings of 4IR skills. The analysis from both the qualitative phase and the industry survey, which were based on the perspectives of industry practitioners, indicates that they emphasize the importance of restaurant workers possessing risk awareness, conducting daily operational handling of technologies, and communication skills. This significant difference arises from the perspective of the trainers and curriculum developers who may perceive that communication skills are not important when using technologies, possibly due to the perception that technology use eliminates the need for communication skills. Additionally, the ability to carry out daily operational tasks with technology is not highly ranked. This discrepancy may stem from the perception among those not directly involved in the industry that operational handling is not a crucial task for restaurant workers, contrary to the perspective of industry practitioners. Synthesizing these findings reveals that industry practitioners are keen on ensuring that workers enhance their communication skills to assist customers in using technologies and to maintain the 'human touch' in the Food Service Industry. Moreover, given the user-friendly functionalities of these technologies, handling the operational functions of these technologies is not challenging for restaurant workers, thus enabling them to communicate clearly with customers regarding any issues faced when using the technologies.

During instrument development of the survey used in the second stage with trainers, the experts validating the survey content and items highlighted that the item on communication skills be reworded to reflect politeness and effective verbal and non-verbal communication skills. Implying that the item on communication skill should be detailed for the respondent to respond more accurately. For higher managerial staff, communication skills are crucial to reflect the culture of the restaurant workers and brand. It is also important to assist customers who struggle when using these technologies as they would want a hassle-free dining experience. Communication skills with technical and maintenance staff are also important to ensure a shorter downtime of using the technologies when there are technical issues. Thus, communication skills are imperative for workers in the Food Service industry regardless of the use of 4IR technologies as these technologies only assist in optimizing work processes, but the dining experience should still be human-centred via effective communication skills.

TABLE 18. 4IR Skills Ranking based on input from industry practitioners and training practitioners of Food Service Industries

4IR Skills Ranking based on Industry Perception	4IR Skills Ranking based on Curriculum Developer and Trainer Perception
1. Risk Awareness	1. Train new employees how to use 4IR technology
2. Daily Operational Handling of 4IR Technology	2. Communicating the technical problems to maintenance personnel.
3. Communication Skills	3. Collaboration with other restaurant sections
	4. Daily operational handling skills of 4IR technology
	5. Risk Awareness

In terms of ranking, the list is a juxtaposition between the ranks of skills perceived by industry practitioners and training practitioners, where it can be seen that the industry feels strongly that risk awareness is a critical 4IR skill, which is not the focus of training practitioners. Additionally, communication skills are entirely absent from the list according to training practitioners' viewpoints.

In summary, the synthesized lists and rankings imply that the key 4IR skills for Food Services workers are Risk Awareness, Daily Operational Handling and Communication Skills. This discrepancy between the industry and training practitioners' views contributes to a skills mismatch within the industry. To address this issue, it is essential to align the TVET curriculum with industry needs by incorporating input from industry practitioners to ensure relevance. The training providers and curriculum developers should, however, ensure that current industry practices are reflected in the curriculum and training experience. These findings stress the importance of aligning TVET curricula with current industry demands. Failure to do so perpetuates the skills gap and affects the overall customer experience in a rapidly digitizing service sector.

CONCLUSION

Contributions to Theory

From the aspect of the methodology used in this study, employing mixed methods allows for the integration of findings from both the qualitative and quantitative phases to enhance the understanding of the 4IR skills needed in the industry. The Sequential Exploratory Mixed-Methods approach also facilitates the analysis of insights from a diverse range of participants in both qualitative and quantitative phases, enabling data triangulation and yielding valuable insights. In terms of multi-methods, in the quantitative phase, non-parametric statistical analysis and Fuzzy Delphi Method analysis were both applied to the different sets of sample respondents. The different methods were applied based on the nature of the sample respondents,where the non-parametric statistical analysis was applied to 93 restaurant workers and the Fuzzy Delphi Method was applied to a sample of heterogeneous experts from whom consensus of answers was a requirement for item selection and rejection from the 4IR framework. Thus, this study contributes to methodology in terms of the mixed-methods and multi-methods approaches applied to synthesize the list of 4IR skills required and how the researcher reasons on the key skills based on input received during the interview sessions with the industry practitioners. This study also highlights the need to consider diverse perspectives to capture the full spectrum of skills required, including communication skills, which were particularly emphasized by industry practitioners.

Contributions to Practice

The findings of this study highlight that there are discrepancies between the perceptions of industry employers and trainers/academicians regarding the 4IR skills required by restaurant workers when using 4IR technologies. Specifically, while industry practitioners emphasized the importance of communication skills, this was less emphasized by trainers and academicians. The discrepancies can be avoided by applying the survey instruments used in this study to be disseminated to industry workers and employers as well as trainers and academicians to obtain a list of the skills inventory required. The skills inventory could be used as a reference for the development of TVET curriculum for the Food Services Industry and also be expanded in future for other industries. Given the rapid pace of technological advancement in the industry, both training institutions and employers should keep abreast of the evolving skill requirements driven by these advancements. Failure to address this could prolong the issue of skills mismatch causing unemployment for graduates who do not possess the skills required by the industry. Ensuring that communication skills are adequately emphasized and integrated into the curriculum is crucial for preparing future-ready graduates who can effectively navigate the complexities of a 4IR-driven workplace.

ACKNOWLEDGMENT

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors would like to thank those involved in the completion of this research.

REFERENCES

Academy of Sciences Malaysia (ASM). (2020). 10-10 Malaysian Science, Technology, Innovation and Economy (MySTIE) Framework. ISBN 978-983-29 15-49-2.

Adler, M., & Ziglio, E. (1996). Gazing into the Oracle: The Delphi Method and its Application to Social Policy and Public Health. London: Jessica Kingsley Publication.

Amiron, E, Abdul Latib, A. & Subari, K. (2019). Industry Revolution 4.0 Skills and Enablers for TVET Curriculum. International Journal of Recent Technology and Engineering. 8 (1C2), 484-490.

Amiron, E. (2020). Industry 4.0 Skills And Enablers For Electronics Manufacturing Industries. [Masters Thesis, Universiti Teknologi Malaysia].

Cheng C.H & Lin Y. (2002). Evaluating the best main battle tank using fuzzy decision theory with linguistic criteria evaluation. European Journal of Operational Research 2002, 142 (1) 74-86.

Chu H. C. & Hwang G. J. (2008). A Delphi-based approach to developing expert systems with the cooperation of multiple experts. Expert Systems with Applications 2008; 34: 28 26-40.

Creswell, John W. (2005). Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research. 2nd ed. Pearson Education, Inc.

Creswell, John W., and Vicki L. Plano Clark. (2007). Designing and Conducting Mixed Methods Research. Sage Publications. ISBN 978-1-4129-2791-8.

Creswell, John W. (2014). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. 4th

ed. Sage Publications. ISBN 978-1-4522-2609-5. 2014.

Creswell, J. W., & Plano Clark, V. L. (2023). Revisiting mixed methods research designs twenty years later. *Handbook of mixed methods research designs*, *1*(1), 21-36.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. Psychometrika, 16, 297–334.

Department of Skills Development (DSD). (2020). Panduan Pembangunan Standard Kemahiran Pekerjaan Kebangsaan Edisi 2020. ISBN 978-967-2393-16-0. 2020

Dieppe, Alistair, (2021). Global Productivity: Trends, Drivers, and Policies. Washington, DC: World Bank. doi:10.1596/978-1-4648-1608-6. License: Creative Commons Attribution CC BY 3.0 IGO

Guest, G., Macqueen, K.M., & Namey, E., E. (2012) Applied Thematic Analysis. Sage Publications. ISBN 978-1-4129 7167 -6

Guest G, Namey E, Chen M (2020) A simple method to assess and report thematic saturation in qualitative research. PLOS ONE 15(5): e0232076. https://doi.org/10.1371/journal.pone.0232076

Hermann, Mario, Tobias Pentek, and Boris Otto. (2016). Design Principles for Industrie 4.0 Scenarios. Paper presented at 2016 49th Hawaii International Conference on System Sciences (HICSS), Koloa, HI, USA, January 5–8, pp. 3928–37.

Hulin, C., Netemeyer, R., & Cudeck, R. (2001). Can a Reliability Coefficient Be Too High. Journal of Consumer Psychology, 10, 55-58. https://doi.org/10.1207/S15327663JCP1001&2_05

Huang, J. (2025). A Literature Review on Firm Internationalization: Theoretical and Conceptual Frameworks. *Journal of Modern Social Sciences*, *2*(2), 154-160.

İlkay, S. Ç., & Bilgili, F. (2025). Assessing the dynamics of international competitiveness based on high-tech exports: insights from a heterogeneous panel of selected G20 countries. *Technology Analysis & Strategic Management*, *37*(1), 65-81.

Izyan Zulkiply, S. R., Jaafar, N., & Faseah Muhamad, N. A. (2024). Fuzzy Delphi Method Application in Developing of Syllabus Quranic Class for Elderly. *Global Business & Management Research*, *16*(2).

Jeganathan, L., Khan, A. N., Kannan Raju, J., & Narayanasamy, S. (2019). On a framework of curriculum for engineering education 4.0. 2018 World Engineering Education Forum - Global Engineering Deans Council, WEEF-GEDC 2018.

Kim, J., & Lee, J. C. (2020). Effects of COVID-19 on preferences for private dining facilities in restaurants. Journal of Hospitality and Tourism Management, 45, 67-70.

Lensing, K., & Friedhoff, J. (2018). Designing a curriculum for the Internet-of-Things-Laboratory to foster creativity and a maker mindset within varying target groups. Procedia Manufacturing, 23, 231-236. https://doi.org/10.1016/j.promfg.2018.04.022

Mehner, L., Rothenbusch, S., & Kauffeld, S. (2025). How to maximize the impact of workplace training: a mixed-method analysis of social support, training transfer and knowledge sharing. *European Journal of Work and Organizational Psychology*, *34*(2), 201-217.

Mohd Jamil, M. R., & Mat Noh, N. (2020). Kepelbagaian Metodologi dalam Penyelidikan Reka Bentuk dan Pembangunan. Bangi: Qaisar Prestige Resources.

Nur Yunus, F. A., Razali, N., Mohd Affandi, H., Kamis, A., Rahim, M. B., Rozali, M. Z., & Sulaiman, J. (2021). Learning Transfer Exploration Model from Skill Institute to Workplace, PLS-SEM Approach. Journal of Technical Education and Training, 13(1). , https://doi.org.10.30880/jtet.2021.13.01.008

Papanai, R., & Poolkrajang, A. (2023). The High Vocational Innovation Scholarship Program: A TVET Curriculum Continuous Quality Improvement Using Feedback from Stakeholders. Journal of Technical Education and Training, 15(4). , https://doi.org.10.30880/jtet.2023.15.04.001

Perkins, D. N., & Salomon, G. (1992). Transfer of learning. International Encyclopedia of Education (2nd ed.). Oxford, UK: Pergamon Press.

Rikala, P., Braun, G., Järvinen, M., Stahre, J., & Hämäläinen, R. (2024). Understanding and measuring skill gaps in Industry 4.0 — A review. *Technological Forecasting and Social Change, 201*, 123206. doi:https://doi.org/10.1016/j.techfore.2024.123206

Roldán López de Hierro, A. F., Sánchez, M., Puente-Fernández, D., Montoya-Juárez, R., & Roldán, C. (2021). A Fuzzy Delphi Consensus Methodology Based on a Fuzzy Ranking. *Mathematics, 9*(18). , https://doi.org 10.3390/math9182323

Saari, A., Rasul, M. S., Mohamad Yasin, R., Abd Rauf, R. A., Mohamed Ashari, Z. H., & Pranita, D. (2021). Skills Sets for Workforce in the 4th Industrial Revolution: Expectation from Authorities and Industrial Players. Journal of Technical Education and Training, 13(2). , https://doi.org.10.30880/jtet.2021.13.02.001

Saldana. J (2013). The *coding manual for qualitative*

researchers. Sage.ISBN 978-1-44624-737-5

Santiago, J., Borges-Tiago, M. T., & Tiago, F. (2024). Embracing RAISA in restaurants: Exploring customer attitudes toward robot adoption. Technological Forecasting and Social Change, 199. doi:10.1016/j.techfore.2023.123047

Schallock, B., Rybski, C., Jochem, R., & Kohl, H. (2018). Learning Factory for Industry 4.0 to provide future skills beyond technical training. Procedia Manufacturing, 23, 27-32. https://doi.org/10.1016/j.promfg.2018.03.156

Schwab, K. (2016). The Fourth Industrial Revolution. ISBN-13: 978-1-944835-01-9

Spöttl,G. (2015). Transformation and Globalization in Technical,Vocational Education and Training – Which Way Should TEVT Take?. World TVET Conference 2015.

Spöttl, G. (2016). Sustainability and competence through TVET in the age of Industry 4.0. TVET International Conference 2016 .

Spöttl, G. & Windelband, L. (2021). The 4th industrial revolution – its impact on vocational skills, Journal of Education and Work, 34:1, 29-52, https://doi.org 10.1080/13639080.2020.1858230

TalentCorp (2021). Critical Occupations List 2020/2021 Occupation Report. Critical Skills Monitoring Committee. Retrieved October 30,2023, from https://www.talentcorp.com.my/images/uploads/publication/184/Critical-Occupations-List-20202021-1704364685.pdf

Tūtlys, V. & Spöttl, G. (2021). Disruption of qualifications in manufacturing: challenges and prospects. European Journal of Training and Development, ahead-of-print (ahead-of-print). doi:10.1108/ejtd-07- 2020-0121

Vernon, R. (1966) International Investment and International Trade in the Product Cycle. The Quarterly Journal of Economics, 80, 190-207.

Wan Hamat, W. N., Muhamad, N., Hashim, A., & Mohamed Yusoff, A. F. (2021). Application of Fuzzy Delphi Technique Towards Designing and Developing the Elements for the e-PBM PI-Poli Module. Asian Journal of University Education, 17(1). , https://doi.org.10.24191/ajue.v17i1.12625

Wermann, J., Colombo, A. W., Pechmann, A., & Zarte, M. (2019). Using an interdisciplinary demonstration platform for teaching Industry 4.0. Procedia Manufacturing. 31. 302-308. https://doi.org/10.1016/j.promfg.2019.03.048

World Economic Forum. (2016). The future of jobs report. Retrieved 7 February 2021, from http://reports.weforum.org/future-of-jobs-2016/

World Economic Forum. (2018). The future of jobs report. Retrieved 7 February 2021, from http://reports.weforum.org/future-of-jobs-2016/

World Economic Forum. (2020). The future of jobs report. Retrieved 2 June 2021, from http://reports.weforum.org

Evarina Amiron & Azlan Abdul Latib,
Universiti Teknologi Malaysia,
Skudai, Johor, 81310, MALAYSIA.

*Corresponding author: evarina@graduate.utm.my