Adapting Technology Adoption Theories to Develop a Fourth Industrial Revolution Skills Acquisition Theoretical Framework

Amiron, Evarina*, Sharom, Khairunnisa, Wimbi Apriwanda Nursiwan

Universiti Teknologi Malaysia, Skudai, Johor, 81310, Malaysia

***Corresponding Author**

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ABSTRACT

This conceptual paper describes the development of a theoretical framework for Fourth Industrial Revolution (4IR) skills acquisition. The framework was derived through a critical analysis of research articles related to technology adoption and technology acceptance, using the SALSA (Search, Appraisal, Synthesis, Analysis) procedure, which identified 15 articles meeting the inclusion criteria. Although the Technology Acceptance Model (TAM) was the most frequently applied theory among the reviewed studies, TAM does not directly explain how technology adoption translates into the specific skills required to operate a technology. The Diffusion of Innovation (DOI) theory was therefore selected as the primary lens, as its innovation-characteristic constructs, namely Low Complexity, Relative Advantage, Compatibility, Result Demonstrability, and Trialability, describe the conditions under which users engage with and learn to use a technology. DOI was integrated with the Technology-Organisation-Environment (TOE) Framework to situate these constructs within technological, organisational, and environmental contexts at both the individual and organisational levels. The resulting DOI-TOE framework was further mapped to the National Occupational Skills Standard (NOSS) to demonstrate its practical application in guiding Technical and Vocational Education and Training (TVET) curriculum development. The framework was subsequently applied and empirically tested in a sequential exploratory mixed-methods study of 4IR skills acquisition among Food Service Industry workers. In that companion study, the DOI factors of Social System, Trialability, Compatibility, and Relative Advantage significantly predicted 4IR skills acquisition, whereas Low Complexity and Result Demonstrability were not significant predictors. These findings provide empirical support for the DOI-TOE integrated framework constructed in this study and extend prior 4IR skills research, which has concentrated on engineering, information technology, and manufacturing contexts, in comparison to the Services Industry.

Keywords: Fourth Industrial Revolution; Technology Adoption and Acceptance; Diffusion of Innovation; Technology-Organisation-Environment Framework; Skills Acquisition.

INTRODUCTION

Fourth Industrial Revolution (4IR) or also known as Industrial Revolution 4.0 (IR4.0) is one of the Industrial Revolutions that has been widely discussed since its inception by the German government in 2011 (Hermann, Pentek, and Otto 2016). The Fourth Industrial Revolution has been discussed in detail by Klaus Schwab in his book on the topic (Schwab 2016) and in the World Economic Forum reports since 2016 (World Economic Forum, 2016). Subsequent research has discussed the impacts of 4IR on the working world (Spöttl & Windelband, 2021). 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, thus operationally defined in this study as 4IR skills. This paper will focus on the process of constructing a theoretical framework that depicts which factors influence skills acquisition when using 4IR technologies in the Services Industry.

It has become apparent that these Service Industry sectors have utilized digitalization and 4IR technologies, especially during the physical contact restriction periods faced in the Covid-19 pandemic from the year 2020 to

early 2022. These technologies include Robotics (e.g. robots serving food in quarantine centres and food outlets), the Internet of Things (e.g. contactless payment), Big Data Analytics (e.g. stores customer data and predicts preference in online food and beverage purchases), Blockchain and Cybersecurity (e.g. e-commerce and customer data). Digitization enables remote work, encompassing tasks such as monitoring, decision-making, collaboration, data sharing, and automation. 4IR technologies build upon digitization to optimize workflows further and integrate existing technologies such as internet connectivity (now known as the Internet of Things), Artificial Intelligence, robotics, system integration, virtual reality, and cybersecurity. Some newer technologies include 3D Printing, Augmented Reality, Advanced Materials, Big Data Analytics, and Cloud Computing. These are classified as Science & Technology Drivers by the Academy of Sciences Malaysia (ASM) and are pivotal for advancement. Malaysia's Economic Planning Unit (EPU) lists fundamental 4IR technologies as Blockchain, Internet of Things (IoT), Cloud Computing, Data Analytics, Artificial Intelligence (AI), and Advanced Materials that underpin advanced 4IR solutions.

Objectives of Research

The objectives of the overall research are to explore factors that influence the skills required for a worker in a working environment that applies 4IR technologies or solutions. It is anticipated that the skills required would be according to the job area, 4IR technology, and occupational level. These aforementioned elements will be depicted in a framework that will guide this research. However, this paper will focus on the process of constructing the framework based on the findings of the literature review conducted to identify theories with variables or factors suitable to the study. As there is no specific theory on how various factors comprising technology, organization, and environment may influence the skills required, the thought process and adaptation from existing theories and models of technology acceptance and adoption and their impact on skills acquisition are the highlights of this paper.

Research Questions

The Research Questions that guide the theoretical framework development are as follows:

1. Which theories are suitable to be extended to study factors that influence the skills required to use Fourth Industrial Revolution (4IR) technologies?

2. Which theory constructs should be included in the theoretical framework to identify factors that influence skills acquisition when using 4IR technologies in the Services Industry?

3. How can the Theoretical framework be structured to include elements from the selected theories?

The research questions above are used as a guide throughout the systematic literature review. From the Research Questions, it can be summarized that the search strategies should ensure that the articles reviewed include discussions on theories, where subsequently from these theories, the researcher can determine which factors influence the skills required for workers in 4IR working environments.

Definitions of the Services Industry

Kakaomerlioglu and Carlsson (1999) defined services to comprise consumer services that are in direct contact with the consumer such as in hospitality, food services, education and healthcare. This study defines the service industry as an industry whose final output is intangible. This definition also implies that the service industry activities may also be provided to other categories of industries. An earlier definition provided by economist, Fisher (1939) as shown in the Fisher-Clark model classified economic activities into primary (agriculture, mining), secondary (manufacturing), and tertiary (services) (Fisher 1939). Tertiary activities that are all economic activities other than agriculture, mining, and manufacturing are defined as service industries. The Fisher-Clark model shows that as a country becomes a high-income nation, the economic growth of the industry sectors moves from primary industries to secondary industries to tertiary industries (services). Whereas producer services are activities related to the mobilization of resources in production and manufacturing such as banking, finance, engineering, recruiting and training, R&D, design and engineering. However, the Organisation for

Economic Co-operation and Development (OECD) (2000) Employment Outlook provided a taxonomy for the service sub-sectors which are producer services, distributive services, personal services, and social services. Producer services are defined as ”intermediate inputs to further production activities which have a high information content and often reflect a “contracting out” of support services that could be provided in-house”.

Related Theories

To construct the theoretical framework, other than understanding the main concepts of the research area, it is also important to understand the related theories that may form the basis of the framework. There are two main types of related theories which are technology acceptance and technology adoption (Venkatesh, Davis, & Morris, 2007).

Technology acceptance theories which include TAM (Technology Acceptance Model) and its variations TAM 2, TAM 3 and UTAUT (Unified Theory of Acceptance and Use of Technology), and UTAUT 2. In general technology acceptance theories focus on understanding how individuals perceive technology within an organizational context. These theories primarily examine factors such as Perceived Usefulness, Perceived Ease Of Use, Social Influence, and the conditions that facilitate the prediction of User Acceptance and Usage Behaviour. TAM (Davis, 1989) posits that Perceived Usefulness and Perceived Ease Of Use influence users' attitudes toward and intentions to use technology. Subsequently, TAM2 which is an extension of TAM by Venkatesh and Davis (2000), incorporates social influence processes (subjective norm, voluntariness and image) and cognitive instrumental processes (job relevance, output quality and result demonstrability) to explain perceived usefulness. TAM3, further extended by Venkatesh and Bala (2008), adds the determinants of perceived ease of use, namely anchors (such as computer self-efficacy and computer anxiety) and adjustments (perceived enjoyment and objective usability). UTAUT (Unified Theory of Acceptance and Use of Technology) introduced by Venkatesh et al. (2003), integrates eight prior models and considers Performance Expectancy, Effort Expectancy, Social Influence, and facilitating conditions to predict user intentions and behaviour. UTAUT2, an extension of UTAUT by Venkatesh et al. (2012), adds hedonic motivation, price value and habit to adapt the model to the consumer context, while retaining age, gender and experience as moderators.

In comparison, Technology Adoption theories such as Diffusion of Innovations (DOI) and Technology-Organization-Environment (TOE) focus on understanding the adoption process of innovations within organizations. DOI developed by Rogers in 1962 explains how innovations diffuse or spread and are adopted among individuals or groups over time. It emphasizes factors such as innovation attributes, communication channels, social systems, and time. TOE by Tornatzky and Fleischer (1990) provides a framework for understanding technology adoption within organizational contexts. It considers technological factors, organizational factors, and environmental factors that influence adoption decisions. While technology acceptance theories focus on individual perceptions and behaviours regarding technology use, technology adoption theories consider broader organizational and environmental factors that influence the adoption process within a specific context.

TAM consists of two main determinants, Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) which are affected by external and context-dependent factors, TAM 2 focuses on the factors influencing PU, TAM 3 focuses on the aspects accountable for PEOU, UTAUT proposed the variables of performance expectancy, effort expectancy, social influence, and facilitating conditions to influence Use Behaviour, whereas UTAUT 2 added hedonic motivation, price value, and habit as influencing factors.

DOI postulates an organisation’s adoption and use of innovations are influenced by innovation characteristics which include high relative advantage, trialability, observability, and compatibility, and low complexity of the technological innovation, and organisational characteristics (individual (leader) characteristics, internal organisational structure characteristics, and the external characteristics of the organization). The TOE framework is derived directly from DOI but extended to observe three aspects that may influence the organizational usage of technological innovation such as the technological context which includes the existing technologies that are available in an organization, the organizational context which refers to the internal measures of an organization such as organizational structure and the environmental context which includes the external environment that the organisation conducts its business such as its industry and related job areas (Tornatzky and Fleischer 1990).

Based on various literature on 4IR, the framework contributes to developing the theoretical framework that will be referred to when analysing the factors that influence the skills required when using 4IR. The methodology and search technique applied to carry out the systematic literature review is explained in the following section, Methods.

METHODS

Literature Review Method

This study employed a systematic literature review using the SALSA framework, which structures the review process into four stages: Search, Appraisal, Synthesis, and Analysis (Grant & Booth, 2009). The SALSA framework is particularly suitable for conceptual and exploratory studies as it provides a transparent and structured approach for identifying, evaluating, and synthesising relevant literature across interdisciplinary research domains, and the choice of review type followed the guidance of Munn et al. (2018).

The purpose of the review was to identify theoretical constructs and empirical findings related to technology adoption and skills acquisition within the context of Fourth Industrial Revolution (4IR) technologies in the service industry. By systematically examining relevant studies, the review aimed to inform the development of a theoretical framework that integrates constructs from technology adoption theories to explain the factors influencing skills acquisition.

Search

The search stage involved identifying relevant literature related to technology adoption, 4IR technologies, and skills acquisition. Academic databases including Scopus and Web of Science were consulted to ensure comprehensive coverage of peer-reviewed publications. The search was conducted using combinations of keywords such as:

- “technology adoption”
- “4IR technologies”
- “skills acquisition”
- “service industry”
- “technology acceptance”
- “digital skills”
- “workforce skills development”

The search focused on journal articles and doctoral dissertations published between 2015 and 2025, reflecting the period in which research on 4IR technologies and digital transformation expanded significantly.

Appraisal

Following the search stage, identified articles were screened and appraised to determine their relevance and quality. Studies were evaluated based on several inclusion criteria:

- relevance to technology adoption or skills acquisition
- focus on organisational or workforce contexts
- discussion of theoretical constructs related to technology adoption

- publication in peer-reviewed academic journals or as examined doctoral dissertations

Articles that did not address technology adoption factors, workplace learning, or skill development were excluded. This appraisal process ensured that only studies contributing meaningful theoretical or empirical insights were included in the review.

Synthesis

The synthesis stage involved organising the selected studies into thematic categories based on the theoretical perspectives and constructs discussed. Particular attention was given to studies referencing major technology adoption frameworks, including the Diffusion of Innovation theory and the Technology–Organization–Environment framework.

Relevant constructs identified in the literature were extracted and categorised according to their conceptual relationships. For example, constructs associated with innovation characteristics were grouped under the DOI theory, while contextual organisational and environmental factors were classified within the TOE framework. This synthesis process enabled the consolidation of key variables from multiple studies, facilitating a clearer understanding of how technology adoption influences skills acquisition in workplace settings.

Analysis

In the final stage, the synthesised literature was analysed to identify relationships among the constructs and to determine how they could be integrated into a coherent theoretical framework. The analysis revealed that innovation attributes from the DOI theory explain individual perceptions of technology adoption, while the TOE framework provides insight into organisational and environmental conditions influencing adoption.

By integrating these theoretical perspectives, the study proposes a theoretical framework that explains how exposure to 4IR technologies within organisational contexts contributes to skills acquisition among workers in the service industry. The framework highlights the role of innovation characteristics and contextual factors in shaping how individuals interact with emerging technologies and develop new competencies.

RESULTS AND DISCUSSION

This section describes the main results and discussion on the process of constructing the theoretical framework for this research based on the article reviewed. The results of the systematic literature review are presented below in alignment with the study's research questions.

Research Question 1: Which theories are suitable to be extended to study factors that influence the skills required to use 4IR technologies?

To identify which theories are suitable to be adapted to analyse factors influencing skills acquisition, a systematic literature review was conducted by applying the SALSA method. The results can be seen in Table 1 which presents the theories/models used in recent studies on the 4IR technology adoption in the Services Industry.

Table 1. Findings from SALSA Review on 4IR Technology Acceptance/Adoption in Service Industries.

No .	Reference	Theories referred	Factors/Constructs/Variables	Article Title
1	Aminoff H, Meijer S, Arnelo U, Frennert S s (2021)	TAM	• Usefulness • Implementation of climate compatibility (Ease of Use)	Telemedicine for Remote Surgical Guidance in Endoscopic Retrograde Cholangiopancreatography: Mixed Methods Study of Practitioner Attitudes

2	Acheampong, R. A., & Cugurullo, F. (2019)	• TAM • Theory of Planned Behaviour (TPB)	• Affective attitude toward AVs • Perceived Benefits of AVs-Instrumental utility • Perceived Benefits of AVs- On-board activities • Fears and Anxiety about AV technology-interaction with other road users • Fears and Anxiety about AV technology-automated system-related • Image • Subjective Norm • Attitude toward technology • Perceived Ease of Use • Perceived behavioral control	Capturing the behavioural determinants behind the adoption of autonomous vehicles: theoretical frameworks and measurement models to predict public transport, sharing and ownership trends of self-driving cars.
3	Alkhwaldi, A. F., Alharasis, E. E., Shehadeh, M., Abu-AlSondos, I. A., Oudat, M. S., & Atta, A. A. B. (2022).	Unified Theory of Acceptance and Use Of Technology (UTAUT)	• Performance Expectancy (PE) • Effort Expectancy (EE) • Social Influence (SI) • Facilitating Conditions (FC) • Personal Innovativeness (PI) • Financial Literacy (FL) • Uncertainty Avoidance (UA)	Towards an Understanding of FinTech Users' Adoption: Intention and e-Loyalty Post-COVID-19 from a Developing Country Perspective
4	Gursoy, D., Chi, O. H. X., Lu, L., & Nunkoo, R. (2019)	TAM	• Social influence (SI) • Hedonic motivation (HM) • Anthropomorphism (A) • Performance expectancy (PE) • Effort expectancy (EE) • Emotion (E) • Willingness to accept the use of AI devices (W) • Objection to the use of AI devices (O)	Consumer's acceptance of artificially intelligent (AI) device use in service delivery.
5	Haneem, F., Kama, N., Taskin, N., Pauleen, D., & Abu Bakar, N. A. (2019).	• Techno logical-Organisational-Environmental (TOE) Framework • Diffusi on of Innovation	• Technological determinants (relative advantage, complexity, quality of master data, and data security) • Organizational determinants (data governance, top management support, and technological competence) • Environmental determinants (government policy, and citizen demand)	Determinants of master data management adoption by local government organizations: An empirical study
6	Han, D. L., Hou, H. Y., Wu, H., & Lai, J. H. K. (2021)	• TAM • TPB (Theory of Planned Behaviour) • Externa l Variables affecting TAM	• Perceived Usefulness (PU), Perceived Ease Of Use (PEU) • Attitude Towards Use (ATU) • Intention To Use (ITU) • Perceived Behavioural Control (PBC) • Subjective Norms (SN) • Perceived Security (PS) Compatibility (COM) • Subjective Norms (SN) • Self-Efficacy (SEL)	Modelling Tourists' Acceptance of Hotel Experience-Enhancement Smart Technologies

7	Lu, L., Cai, R., & Gursoy, D. (2019)	TAM	• Performance efficacy • Intrinsic motivation • Anthropomorphism • Social influence • Facilitating Conditions • Emotions	Developing and validating a service robot integration willingness scale
8	Park, H. K., Chung, J., & Ha, J. (2023)	Technology Acceptance Model (STAM)	• Technology Acceptance • Internal abilities • External controls • Quality of life • Attitudinal beliefs • Cognitive health • General Health • Social health/Social support • Gerontechnology anxiety	Acceptance of technology related to healthcare among older Korean adults in rural areas: A mixed-method study
9	Qasem, Y. A. M., Abdullah, R., Jusoh, Y. Y., Atan, R., & Asadi, S. (2021).	TOE framework IS (Information System) Continuance Model	• Technological context (Net Benefits, System Quality, Information Quality and Technical Integration) • Organisational context (System Investment and Collaboration • Environmental context (Regulatory Policy and Competitive Pressure)	Analyzing Continuance of Cloud Computing in Higher Education Institutions: Should We Stay, or Should We Go?
10	Oni, A. A., Musa, U., & Oni, S. (2020).	TOE Framework	• Infrastructure revenue know-how • Financial Cost • Internal need • Satisfaction with existing system • Competitive Pressure Taxpayers' readiness • Government regulation • E-revenue adoption	E-Revenue Adoption in State Internal Revenue Service: Interrogating the Institutional Factors
11	Singh, S., & Srivastava, P. (2019)	TAM	• Perceived Usefulness (PU) Perceived Ease Of Use (PEU) • Perceived Trust (PT) • Social Capital (SC) • Disposition Readiness (DR)	Social media for outbound leisure travel: a framework based on technology acceptance model (TAM).
12	Borgen, I. (2023)	TAM	Variables/Constructs for Evaluation of Patient Satisfaction With Telemedicine • Usefulness • Technical quality • Effect on interaction • Effectiveness • Experience • Overall satisfaction Variables/Constructs for Evaluation of Provider Satisfaction with Telemedicine • Usefulness • Technical quality • Effect on interaction, effectiveness, • Experience • Overall satisfaction	Patient and Provider Satisfaction and Provider Intent to Use Virtual Video Technology for Medical and Surgical Visits in an Urban Ambulatory Setting During and in Peri-COVID-19 Era.

13	Parmanto, B., Lewis Jr, A. N., Graham, K. M., & Bertolet, M. H. (2016).	TAM	• Usefulness • Ease Of Use And Learnability • Interface Quality Interaction Quality • Reliability • Satisfaction And Future Use	Development of the telehealth usability questionnaire (TUQ).
14	Zheng, J. H., & Khalid, H. (2022)	Technological-Organisational-Environmental (TOE) Framework and Diffusion of Innovation (DOI)	• Technology factors (Artificial Intelligence Tools, Perceived Usefulness, Compatibility, Big data Analytics Ability, and Cloud Commuting Facility on the ERPBI adoption) • Organizational factors, (Top Management Support, Training, Communication, and Relative Advantage on the ERPBI adoption) • Environmental factors (Competitiveness Pressure, Firm Size, and Pandemic Recovery Plan, on the adoption of ERPBI.)	The Adoption of Enterprise Resource Planning and Business Intelligence Systems in Small and Medium Enterprises: A Theoretical framework
15	Hiran, K. K., & Henten, A. (2020).	Technological-Organisational-Environmental (TOE) Framework and Diffusion of Innovation (DOI)	• Sociocultural factors (Value, language, awareness, societal belief) • Economic factors (Per capita income, cost, govt. grants, infra development)	An integrated TOE–DoI framework for cloud computing adoption in the higher education sector: case study of Sub-Saharan Africa, Ethiopia

Based on Table 1, in the context of the Services Industry, several theories are mostly referred to in research on 4IR technologies in recent years (2016–2023). These theories are the Technology Acceptance Model (TAM), Technological Organisational Environmental (TOE) framework, Diffusion of Innovation (DOI) and Unified Theory of Acceptance and Use Of Technology (UTAUT). TAM is mostly used to analyze the factors influencing an individual's acceptance of new technology as seen in research by Aminoff H et al. (2021), Borgen, I. (2023), Gursoy, D., et al.(2019), Lu, L et al. (2019), and Parmanto, B., et al. (2016). Most of the studies that were in the context of the service industry were in the context of hospitality and health services. The variables that were prevalent among these studies were Perceived Ease of Use and Perceived Usefulness. Although these two variables may seem simplistic compared to the other extensions of TAM, they are still the most commonly analysed variables because these variables are more easily observed. Furthermore, it is more practical to analyze the acceptance of 4IR technology in the services industry which revolves around ensuring the customer experience is hassle-free and effective, or as depicted by TAM's variables, easy-to-use and useful.

During the review, variations of applying the technology acceptance or adoption theories were also observed. For examples of TAM, research by Borgen (2023) observed TAM from two perspectives which were from the patient's perspective and the service provider's perspective. This proved to be a more holistic analysis of the technology being introduced, as gaps between the satisfaction of both groups of users could be identified. Gursoy (2019) took the approach of observing the constructs of how AI is accepted in Service Delivery by customizing the variables according to AI characteristics. For example, one of the variables, anthropomorphism looks at how the AI device's humanlike characteristics may affect the consumer's perception of effort expectancy. In research by Park, H. K., Chung, J., & Ha, J. (2023), TAM was modified to become the Seniors Technology Acceptance Model (STAM), where the constructs that were analysed included Gerontechnology anxiety which is specific for the elderly.

Table 1 also shows that the Unified Theory of Acceptance and Use of Technology (UTAUT) was applied by Alkhwaldi et al. (2022), while Gursoy et al. (2019) and Lu et al. (2019) incorporated UTAUT constructs such as performance expectancy, effort expectancy, social influence and facilitating conditions into extended TAM models. Theory of Planned Behaviour (TPB) in research by Acheampong, R. A., & Cugurullo, F. (2019) was used to form an extended TAM model for explaining their influence on behavioural intention.

To investigate technology adoption in the service industry, the DOI theory is typically applied in situations of new technology diffusion. DOI investigates new technology diffusion (Rogers 1983) that postulates an organisation's adoption leading to the use of innovations (which in the context of this research will result in the acquisition of skills to utilise the innovation) are influenced by innovation characteristics and organisational characteristics. The innovativeness characteristics imply that innovations or 4IR technologies with the characteristics listed in the DOI theory are more easily accepted thus motivating users to acquire the skills to utilise them. Organisational characteristics comprise three groups of drivers: individual (leader) characteristics, internal organisational structure characteristics, and external characteristics of the organisation. The external characteristics of an organisation refer to social systems or system openness, which is similar to the environmental context in the Technology-Organisation-Environment (TOE) framework.

Overall, by referring to the context of this study which is to analyse the factors that influence the skills required to utilize 4IR technologies, it can be concluded that the theories relevant to this study are TAM, DOI theory and TOE Framework. Throughout the literature review, it was clear that TAM is a prominent theory used by researchers to study the factors that influence the acceptance of new technology such as 4IR which includes robots, Business Intelligence, and the Internet of Things among others. Although TAM is considered as being simplistic and does not address other factors that influence technology adoption, TAM is still made the basis of most research that has expanded the TAM model. However, TAM focuses more on factors that influence individual end-users' acceptance of technology and does not explore further whether skills to use the technologies will be adopted. The context of this study is to identify factors that lead to the acquisition of skills required to utilize 4IR technologies, which can be explained via the technology adoption theory DOI. This is because DOI elaborates that knowledge of an innovation's functionality and operational handling will lead to the individual acquiring the skills to use the technology. This knowledge includes: Awareness-Knowledge – Which is the cognitive stage of learning that motivates individuals to learn more about the innovation and eventually adopt it; How-To- Knowledge - Which contains information on how to use the innovation correctly; and Principles-knowledge - Includes the 'how' and 'why' an innovation works. However, innovation can still be adopted without principles-knowledge, but if misused, some individuals may choose not to use the innovation (Rogers 1983).

Furthermore, the overall goal of this research is to assist in updating TVET curriculum to accommodate 4IR skills, therefore, other than observing factors that influence adoption of technology (that ultimately will lead to the end user learning the skills to use the technology) it is also important to observe an alignment between elements of TVET curriculum that determines the level of skills competency required to utilize the 4IR technology applied in the services working environment. TVET curriculum in Malaysia which is the National Occupational Skills Standards (NOSS), is based on the job's expected minimum and standard skills and competencies that a worker for a particular job area and level should possess. In the NOSS, the job area determines the scope of work and the occupational level determines the level of competency that a worker should possess. Following this, in the NOSS, the technology and tools required to carry out the work are also included. The theory that has similar variables as the aforesaid characteristics of the NOSS is the Technological-Organisational-Environmental (TOE) framework.

The TOE framework consists of three key determinants that influence organisational adoption of technology which are technological, organizational and environmental. Research on technology adoption at organisational level are such as at local governments, higher education institutes, state agencies, and SMEs. The TOE framework is referred to in this particular study to analyze external factors that may influence the adoption of skills required for an occupation such as technologies used, organizational structure (occupational level), and environmental factors such as (job scope which include industry characteristics and regulatory requirements). At this point of time, there are no specific models related to elements that influence the skills of workers,

therefore this study will refer the TOE framework. This is because the acceptance of an innovation would subsequently lead to the user learning the skills required to utilize the technology. The elements of the TOE frameworks are interpreted in this study as the Independent Variables which are Technology (technological determinant), Occupational areas (environmental determinant), and Occupational levels (organizational determinant). These are considered Independent Variables because they are not influenced by other elements but they play a major role in determining the required skills.

Due to the context of this study that aims to analyse the factors that influence a worker to acquire the skills to use 4IR technologies in the working environment, the technology adoption theories DOI and TOE are applied in this study. Figure 1 summarises the theories, key determinants and application domains identified in the reviewed studies.

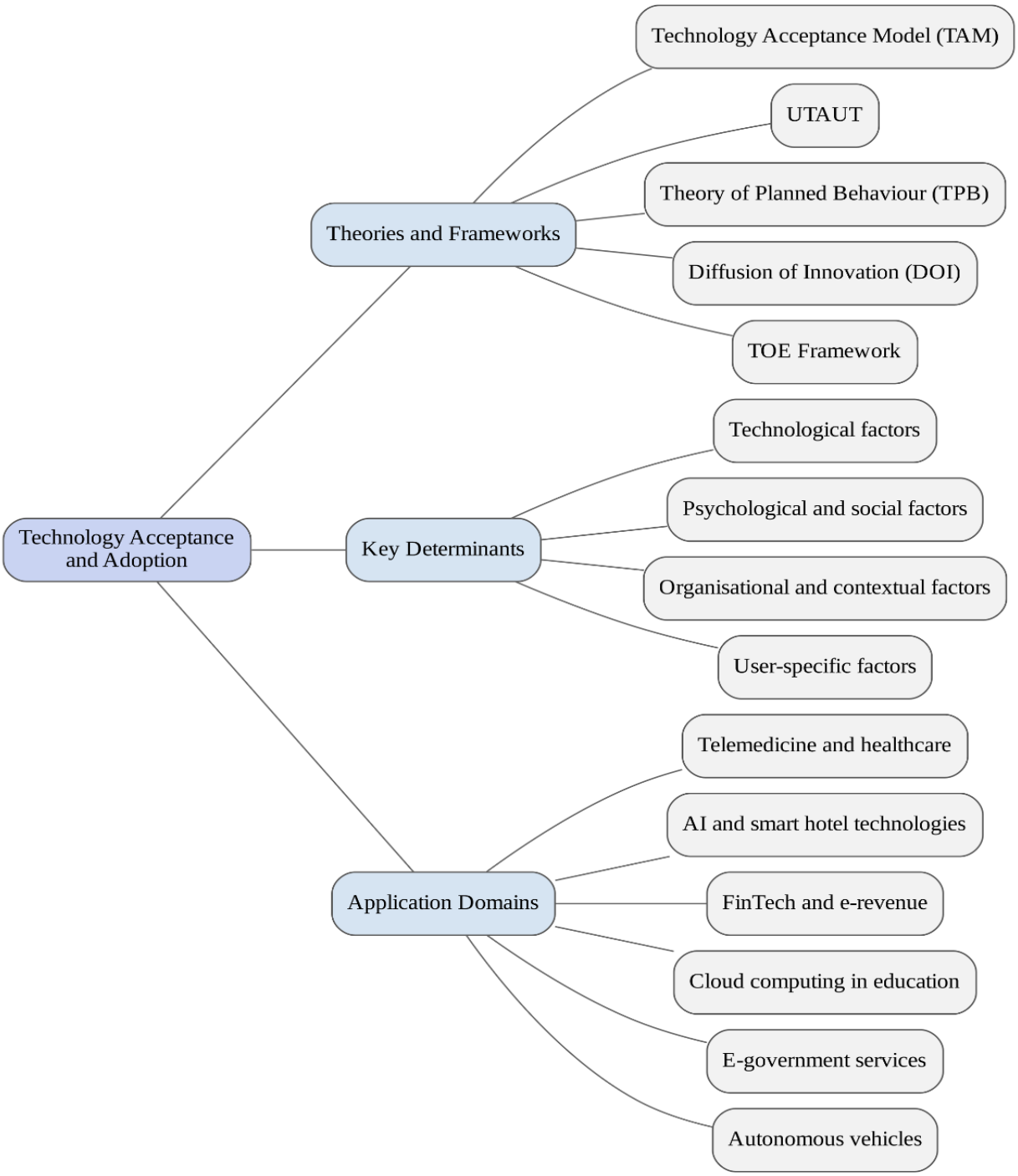


Figure 1. Overview of Theories, Key Determinants and Application Domains Identified in the Reviewed Studies

Research Question 2: Which theory and constructs should be included in the framework to identify factors that influence skills required when using 4IR technologies in the Services Industry?

The Diffusion of Innovation Theory and Technological-Organizational-Environmental (TOE) Framework are selected for integration in this study by examining how the factors of these theories influence the adoption of new technologies and skills. This is also to gain a more comprehensive understanding of the factors that influence skills adoption as a result of organisations adopting new technologies.

This study will apply an integrated DOI-TOE framework which has been applied in previous research by Haneem et al. (2019), Hiran and Henten (2020) and Zheng and Khalid (2022). Following Moore and Benbasat (1991), Rogers' Observability is operationalised in this study as Result Demonstrability, and Complexity is expressed in its positive form as Low Complexity. The DOI Innovative Characteristics of Trialability, Result Demonstrability, Compatibility and Low Complexity are considered to be under the Technological Context of TOE as these are closely related to the characteristics of the technology being used and its characteristics influence the skills required to use the technology. Whereas DOI's Relative Advantage factor is considered to be similar to TOE's Organisational Context as this study will analyse the advantage of using the technology concerning the dynamics between the workers in the internal organizational structure of the F&B outlet. Lastly, DOI's Social System is similar to TOE's Environmental context, where in this study the communication between parties relevant to the F&B outlet is analysed. Although Rogers (1983) treats the social system as an element of the diffusion process rather than as an attribute of the innovation itself, it is retained here as a factor because communication with customers, suppliers and regulators shapes how workers learn to use a technology.

The findings have highlighted that the Diffusion of Innovation (DOI) theory by Rogers (1983) and the Technological-Organisational-Environment (TOE) Framework by Tornatzky and Fleischer (1990) were relevant to this study because DOI focuses on technology adoption where the innovative characteristics may facilitate the adoption of the technology and concurrently acquire the skills to use the technology. TOE expands this to encompass technological, organizational, and environmental factors which are matched to the DOI's factors influencing technology adoption, thus integrating elements from DOI and TOE. The theoretical framework which integrates the two theories enables a comprehensive study to be done that examines factors influencing skills acquisition resulting from technology adoption, as seen in prior research (Haneem et al. 2019; Hiran and Henten 2020; Zheng and Khalid 2022;).

Table 2. Integration of DOI and TOE Constructs for Developing the Theoretical framework

Theoretical Source	Construct	Corresponding TOE Context	Operational Interpretation in This Study	Implication for Skills Required in 4IR Technologies Usage
Diffusion of Innovation (DOI)	Trialability	Technological Context	The extent to which workers can experiment with new technologies before full implementation	Workers require exploratory digital skills and the ability to learn through experimentation when interacting with emerging technologies
Diffusion of Innovation (DOI)	Result Demonstrability (Observability)	Technological Context	Visibility of the outcomes and benefits of using the technology within the organisation	Employees develop awareness of technological processes and analytical skills through observing technology usage and outcomes
Diffusion of Innovation (DOI)	Compatibility	Technological Context	Degree to which the new technology aligns with existing workflows and operational processes	Workers must adapt existing operational skills to integrate new digital and automated technologies

Diffusion of Innovation (DOI)	Low Complexity	Technological Context	The extent to which the technology is perceived as easy to understand and use (the positively worded form of Rogers' Complexity)	Lower complexity eases skills acquisition; where complexity is high, workers require advanced technical, digital literacy and troubleshooting skills
Diffusion of Innovation (DOI)	Relative Advantage	Organizational Context	The perceived improvement in work performance or productivity resulting from technology adoption	Employees must develop new competencies to maximise productivity and operational efficiency when using advanced technologies
Diffusion of Innovation (DOI)	Social System	Environmental Context	Influence of external stakeholders such as industry partners, suppliers, and regulatory bodies on technology adoption	Workers may require collaborative, communication, and technology coordination skills when interacting with external actors
Technology–Organization–Environment (TOE)	Technological Context	Technological Context	Availability and characteristics of 4IR technologies within the organisation	Determines the level of technical and digital skills required to operate emerging technologies
Technology–Organization–Environment (TOE)	Organizational Context	Organizational Context	Internal organisational factors such as management support, resources, and training opportunities	Influences the development of workplace learning and technology-related skill development
Technology–Organization–Environment (TOE)	Environmental Context	Environmental Context	External pressures including industry competition, regulatory requirements, and technological trends	Encourages continuous skills upgrading and adaptation to evolving industry technologies

To address Research Question 2, the constructs of the Diffusion of Innovation (DOI) theory and the Technology–Organization–Environment (TOE) framework were integrated to identify factors influencing the skills required when using 4IR technologies in the services industry. The DOI constructs explain how characteristics of technological innovations influence technology adoption, while the TOE framework provides a broader contextual perspective encompassing technological, organizational, and environmental factors. Table 2 summarises how constructs from both theories were aligned and operationalised in this study to explain the relationship between technology adoption and skills acquisition.

Research Question 3: How can the Theoretical framework be structured to include elements from the selected theories?

The integrated DOI-TOE theoretical framework considers DOI's Innovative Characteristics (Trialability, Result Demonstrability, Compatibility, Low Complexity) within TOE's Technological Context. DOI's Relative Advantage aligns with TOE's Organizational Context when analyzing technology benefits within organizational structures. DOI's Social System corresponds to TOE's Environmental context, examining influences from relevant parties. The resulting framework is illustrated in Figure 2.

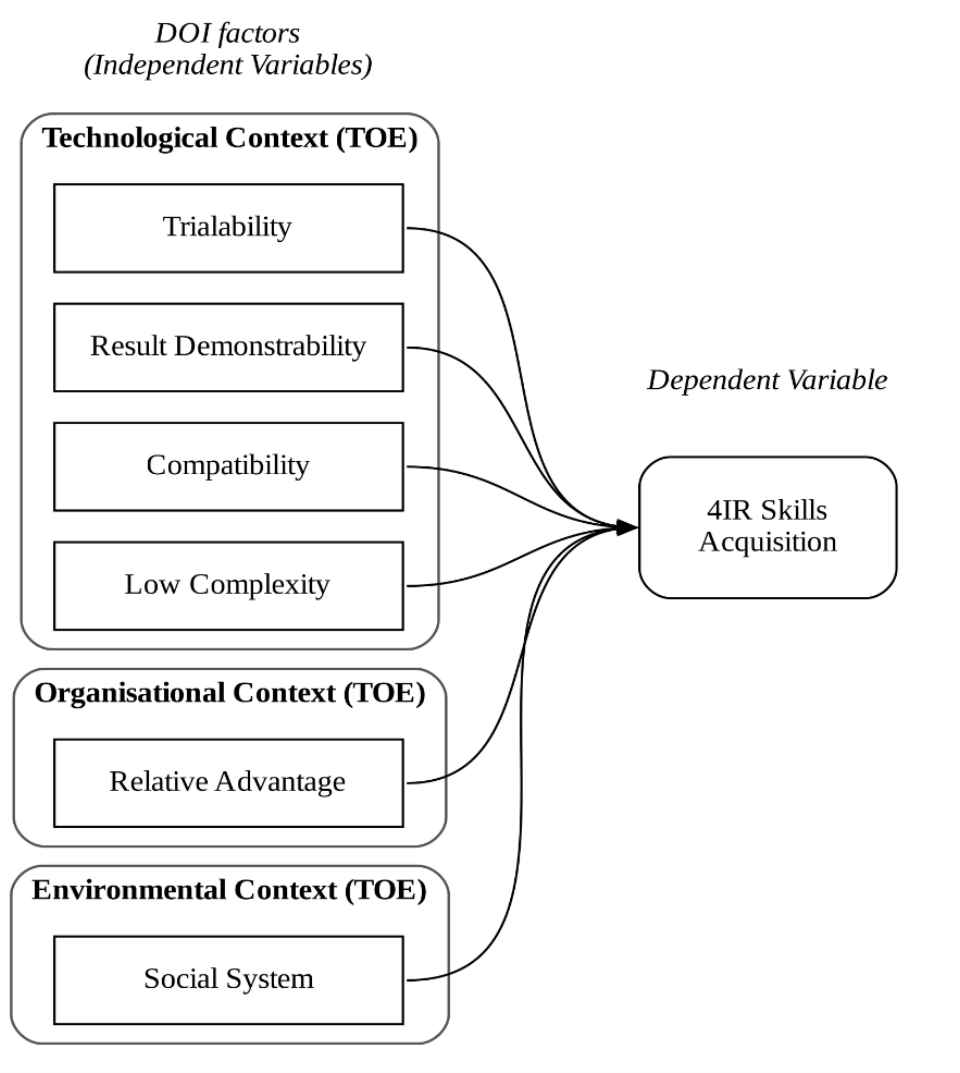


Figure 2. Theoretical framework Comprising TOE and DOI factors

The integration of DOI and TOE frameworks in this study is further supported by previous research that has successfully applied these models to analyse technology adoption in various industries. Studies by Haneem et al. (2019), Hiran and Henten (2020), and Zheng and Khalid (2022) have demonstrated the efficacy of combining these frameworks to provide a distinct understanding of technology adoption dynamics. Based on what was done in these previous studies, this research will map the factors of DOI and TOE.

The DOI Innovative Characteristics of Trialability, Result Demonstrability, Compatibility and Complexity are considered to be under the Technological Context of TOE as these factors are closely related to the characteristics of the technology being used and its characteristics that may influence the skills acquisition to use the technology. However, in this study, the variable Complexity was rephrased as Low Complexity so that survey items could be worded in a consistent positive direction, avoiding the need to reverse-code responses and aligning it with the positively-worded items used for the other DOI constructs in the subsequent empirical validation of this framework.

DISCUSSION

The theoretical framework constructed through this systematic literature review addresses a gap identified across the reviewed studies. While the Technology Acceptance Model (TAM) was the most frequently applied theory among the analysed articles, TAM primarily explains adoption through perceived usefulness and ease of use, and does not directly account for how technology adoption translates into the specific skills required to operate a technology. The Diffusion of Innovation (DOI) theory was therefore selected as the primary lens, as its innovation-characteristic constructs (Trialability, Result Demonstrability, Compatibility, Low Complexity,

Relative Advantage) describe not only whether a technology is adopted but the conditions under which users engage with and learn to use it. Integrating DOI with the Technology-Organisation-Environment (TOE) framework further situates these constructs within the technological, organisational, and environmental contexts already used to structure TVET curriculum components, which is central to this framework's intended application (Table 3).

This framework also extends prior research on 4IR-related skills frameworks, which has concentrated disproportionately on engineering, Information Technology, and manufacturing contexts. Prifti et al. (2017) developed a 4IR competency model limited to engineering, IT and Information Systems roles, while Amiron (2020) proposed a matrix of 4IR skills specific to the Electronics Manufacturing Industry. Maisiri and Van Dyk (2019) and Akyazi et al. (2020) each called for this line of research to be extended to industries beyond engineering and ICT. By constructing a DOI-TOE integrated framework for the Services Industry, this study responds directly to that call, while also incorporating both technical and non-technical skill dimensions, consistent with findings from Rampasso et al. (2019) and the World Economic Forum (2016, 2018) that both skill categories are required when adopting 4IR technologies, and with Amiron (2020) that even non-technical skills are technology-specific rather than generic.

The practical value of the resulting framework lies in how its DOI factors map onto TOE's technological, organisational, and environmental contexts, which in turn correspond to structural components already present in the National Occupational Skills Standards (NOSS), as detailed in Table 3. This alignment is what allows the framework to move from a purely theoretical construct to one that can guide TVET curriculum content directly, and thus demonstrating the practical application of the framework structure developed under Research Question 3.

Implications for Practice: Mapping of the 4IR Skills Acquisition Framework to TVET Curriculum (NOSS)

The 4IR skills framework developed in this study incorporated the Diffusion of Innovation (DOI) Theory and Technology-Organization-Environment (TOE) Framework. The framework is mapped to the National Occupational Skills Standard (NOSS) elements to analyse 4IR skills acquisition in the Food Service Industry. The DOI theory provides insights into how 4IR skills are acquired as a result of technology adoption in the Food Service Industry. The TOE framework helps identify technological, organisational and environmental factors that influence technology and skills adoption. Whereas the NOSS serves as a structural guide, ensuring that 4IR skills align with competency-based training standards. This section evaluates the effectiveness of this framework in addressing the research questions and highlights potential improvements for broader applicability.

The selection of elements in the 4IR skills framework was based on two key criteria: relevance to the Service Industry and alignment with NOSS. Given the increasing integration of 4IR technologies in service industries, the framework had to capture how different stakeholders (e.g. workers, trainers & curriculum developers) interpret these skills. Whereas mapping to the NOSS requires the framework to include elements such as 4IR skills and the factors of DOI and TOE theories' to be aligned with the NOSS document's main elements. To ensure seamless integration of 4IR skills into existing TVET curriculum, the framework elements were systematically mapped onto NOSS sections. Table 3 provides a detailed comparison, highlighting where each component of the 4IR skills framework aligns within the NOSS. The mapping is done based on the operational definition of the 4IR skills framework elements and the corresponding definition of NOSS elements. This mapping is also referred to when embedding 4IR skills into the NOSS sections.

The 4IR skills are mapped to the 'Work Activities – Step', in the Competency Profile and 'Related Skills' and 'Attitude' in the Curriculum of Competency Unit (CoCU) (DSD, 2020) because these sections list the required skills. The Related Skills are usually technical skills, whereas Attitude comprises soft skills. The 4IR technologies are mapped to the Tools, Equipment and Material (TEM) section of the NOSS (DSD, 2020). The DOI and TOE factors are mostly mapped to the relevant sections under the Competency Profiles and CoCU. For example, the DOI factor, Social Systems and TOE Environmental factor are mapped to Core Abilities. However, Core Abilities are not included in the NOSS but are available as a different document which is referred to when developing the Core Abilities training material (DSD, 2020).

Table 3. Mapping between NOSS and 4IR Skills Framework Elements

NOSS Section	4IR Skills Framework											
	Reasons for using 4IR	TOE Factor			DOI Factor						4IR skills	4IR Technologies
		T	O	E	C	RD	LC	Tr	RA	SS		
Standard Practice	X									X		
Competency Profile												
Descriptor	X									X		
Work Activities – Step		X	X		X				X		X	
Performance Criteria						X			X			
Curriculum of Competency Unit (CoCU)												
Learning Objectives	X						X					
Work Activity				X								
Related Knowledge		X										
Related Skills		X			X		X				X	
Attitude and Safety				X							X	
Assessment criteria	X					X						
Tools, Equipment and Material (TEM)								X				X
Core Abilities				X						X		

Legend:

T: Technological Factor O: Organisational Factor E: Environmental Factor C: Compatibility

LC: Low Complexity Tr: Trialability

RD: Result Demonstrability RA: Relative Advantage SS: Social System

X: Corresponding NOSS Element

Limitations and Future Research

This study has several limitations. First, the review drew mainly on Scopus and Web of Science and included 15 studies that met the inclusion criteria, so relevant work indexed elsewhere may have been missed. Second, most of the reviewed studies examined technology acceptance or adoption rather than skills acquisition directly; the link between adoption and skills acquisition is therefore derived from the DOI and TOE theories rather than from studies that measured it. Third, the framework was developed for, and subsequently tested in, the Food Service Industry, so its applicability to other service sub-sectors such as healthcare, tourism and finance should be examined in future studies. Future research may also examine how the framework can be embedded in the NOSS development process for other occupational areas.

Beyond these limitations, four extensions to the framework are recommended for future research. First, future studies should synthesise acceptance theories with cognitive learning theories. The present framework builds on technology adoption theories (DOI and TOE), and the reviewed literature was dominated by acceptance models such as TAM and UTAUT. These models explain the decision to adopt a technology but say little about the learning process through which the skills to use it are acquired. Future frameworks should therefore not rely on TAM or UTAUT alone, but explicitly integrate educational theories such as Bandura's (1997) Self-Efficacy Theory and Sweller's (1988) Cognitive Load Theory. Self-efficacy would capture workers' belief in their ability to master a 4IR technology, while cognitive load would capture the mental effort and friction involved in learning complex 4IR domains. Together, they would allow the learning journey from adoption to competence to be mapped more accurately.

Second, future work should introduce dynamic agility, or adaptability, as a core construct. The current

framework treats 4IR skills acquisition as a relatively static outcome. Because 4IR tools evolve rapidly, this static outcome variable could be replaced by a construct centred on continuous learning or learning agility (DeRue, Ashford, & Myers, 2012). Such a construct would explicitly measure an individual's capacity to unlearn old technical workflows and rapidly acquire new ones as tools evolve, reflecting that 4IR competence is not acquired once but must be renewed throughout working life.

Third, future models should account for institutional coercion versus voluntariness. In many workplaces, 4IR skills are learnt because the employer mandates them rather than by choice. Voluntariness of use is already recognised as a moderator in UTAUT (Venkatesh et al., 2003), and the significant effect of the Social System factor in the companion study suggests that organisational and social pressures matter. Adding institutional mandate as a moderating variable would help differentiate between employees who learn a 4IR skill because they are genuinely motivated and those who do so purely to avoid layoffs, a distinction that may affect the depth and persistence of the skills acquired.

Finally, future research should incorporate perceived risk of undesirability as a modern psychological driver of skills acquisition. This construct would measure a worker's fear of automation or career displacement (Brougham & Haar, 2018). In the 4IR era, anxiety and the desire for job security may be far more powerful drivers of skills acquisition than perceived ease of use. This is consistent with the companion study, in which Low Complexity, the DOI counterpart of perceived ease of use, did not significantly predict 4IR skills acquisition. Measuring perceived risk of undesirability would help explain why workers invest in learning 4IR skills even when the technology is perceived as complex.

CONCLUSION

The theoretical framework that is the result of this systematic literature review can be applied as a guide for studies on the factors that influence technology leading to skills acquisition when using the particular technology. It combines two theories of technology adoption to observe the factors by using the DOI theory whilst mapping these factors to components of TVET curriculum which are apparent in the TOE framework. The findings have shown that the most referred theory in the analysed articles has been TAM, however, this theory does not observe the factors from an angle that looks at how the technologies are adopted and influence the acquisition of skills to use a technology. The DOI theory is referred as it analyses a wide number of factors that can be mapped to TOE and components of TVET curriculum which are Technology used, the Organisational factor reflects the occupation that the TVET training is designed for, and finally the Environmental factor that measures the social systems and regulations that influences the adoption of technology. This framework has since been applied and empirically tested in a subsequent sequential exploratory mixed-methods study of the Food Service Industry. In that study, the DOI factors of Social Systems, Trialability, Compatibility and Relative Advantage were found to significantly predict 4IR skills acquisition among restaurant workers, whereas Low Complexity and Result Demonstrability were not significant predictors in this context. These findings provide empirical support for the DOI-TOE integrated framework constructed in this study and are reported in full in a companion publication.

Ethical Considerations

This paper reports a conceptual literature review and did not involve primary data collection from human or animal subjects; therefore, ethical approval was not required for this study. The subsequent empirical validation of the framework referenced in the Conclusion was conducted under separate ethical approval and is reported in full in its companion publication.

Conflict of Interest

The author declares no conflict of interest.

Data Availability

This study is based on secondary data derived from previously published literature. All sources analysed are cited in the reference list and are publicly accessible through their respective publishers or databases. No new primary dataset was generated for this study.

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