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The Influence of Social Influence, Cost-Effectiveness, and Personal Innovativeness on E-Learning Adoption: The Mediating Role of Self-Efficacy

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Abstract

The rapid advancement of Industry 4.0 technologies has significantly increased the need for continuous skill development among engineers in the manufacturing sector. While e-learning has emerged as a flexible and scalable solution, its adoption remains inconsistent across organisations. E-learning has emerged as a flexible and scalable solution to support professional learning; however, its adoption remains inconsistent. This study aims to develop a conceptual framework to better understand the factors influencing e-learning adoption among engineers in Malaysia's manufacturing industry by integrating Innovation Diffusion Theory and Social Cognitive Theory. The framework examines the influence of social influence, cost-effectiveness, and personal innovativeness on e-learning adoption, with self-efficacy as a mediating variable. It is argued that although external and individual factors may encourage initial adoption, self-efficacy plays a crucial role in translating these influences into sustained engagement. By positioning self-efficacy as a central mechanism, the study offers a more nuanced explanation of digital learning behaviour in Industry 4.0 environments. The study contributes to theory by integrating macro-level and micro-level perspectives and offers practical implications for organisations and policymakers seeking to enhance workforce sustainability through e-learning. Future research is recommended to empirically validate the proposed framework across different industrial contexts.

Keywords: Industry 4.0, E-learning Adoption, Self-Efficacy, Social Influence, Personal Innovativeness, Cost-Effectiveness, Manufacturing Industry

Introduction

The emergence of Industry 4.0 has significantly transformed manufacturing systems, organisational processes, and workforce requirements (Lasi et al. (2014); Kagermann et al.

(2013)). The integration of advanced technologies such as artificial intelligence, cyber-physical systems, the Industrial Internet of Things (IIoT), and big data analytics has accelerated the shift toward highly automated and digitally interconnected production environments. As a result, there is an increasing demand for engineers who possess not only technical expertise but also the ability to continuously adapt to evolving technologies (Frank et al., 2022; Tortorella et al., 2023).

In this context, the traditional skillsets of engineers are becoming rapidly obsolete due to the fast pace of technological advancement (World Economic Forum (2020); Schwab (2016)). Continuous learning is no longer optional but has become a critical necessity for sustaining workforce relevance and organisational competitiveness (Noe et al. (2014); OECD (2019)). In Malaysia, the manufacturing sector remains a key contributor to economic growth, supported by national initiatives such as Industry4WRD, which aim to accelerate digital transformation (Industry4WRD). However, despite these efforts, significant gaps persist in workforce readiness, particularly in the adoption of digital technologies and continuous professional development practices (SME Corp Malaysia (2019)).

Conventional training approaches are increasingly inadequate in addressing these challenges. Traditional face-to-face training methods are often constrained by time, cost, and operational limitations, making them less suitable for engineers working in production-intensive environments (Salas et al. (2012)). In contrast, e-learning offers a flexible, scalable, and accessible solution that enables continuous skill development without disrupting work commitments. Despite its advantages, the adoption of e-learning among engineers remains inconsistent, indicating that technological availability alone does not guarantee utilisation (Sun et al. (2008); Tarhini et al. (2017)).

Despite the recognised importance of e-learning in supporting continuous professional development, its adoption among engineers in Malaysia's manufacturing sector remains uneven and limited (Ramayah et al. (2018); SME Corp Malaysia (2019)). Existing studies have largely focused on technological and organisational factors, with insufficient attention given to the combined influence of social, economic, and individual behavioural determinants (Venkatesh et al. (2003); Tarhini et al. (2017)). In particular, the role of self-efficacy as a mediating mechanism in influencing e-learning adoption has not been adequately explored (Bandura (1997); Zimmerman and Kulikowich (2016)). This gap limits the understanding of how external influences and individual cognitive factors interact to shape adoption behaviour in Industry 4.0 environments.

To address this gap, this study integrates Innovation Diffusion Theory (IDT) and Social Cognitive Theory (SCT) to develop a comprehensive framework explaining e-learning adoption behaviour among engineers. By examining both external determinants and internal cognitive mechanisms, the study provides a more holistic understanding of digital learning adoption. Therefore, this study aims to examine the determinants of e-learning platform adoption among engineers in Malaysia's manufacturing industry. Specifically, the study investigates the direct effects of social influence, cost-effectiveness, and personal innovativeness on e-learning adoption. In addition, it explores how these factors influence engineers' self-efficacy in adopting e-learning platforms. The study further examines the effect of self-efficacy on e-learning adoption and evaluates its mediating role in the

relationships between social influence, cost-effectiveness, personal innovativeness, and the adoption of e-learning platforms.

Theoretical Foundations

This study is grounded in two complementary theoretical perspectives, namely Innovation Diffusion Theory (IDT) and Social Cognitive Theory (SCT). These theories provide a comprehensive foundation for understanding e-learning adoption by integrating external environmental influences with internal cognitive processes.

Innovation Diffusion Theory

Innovation Diffusion Theory (Rogers, 2003) explains how new technologies and ideas are communicated and adopted within a social system over time. The theory emphasises that adoption behaviour is influenced not only by the characteristics of the innovation itself but also by social interactions, communication channels, and individual differences among users.

Within organisational contexts, IDT highlights the importance of social influence and personal innovativeness as key determinants of technology adoption. Social influence refers to the extent to which individuals perceive that important others such as supervisors, colleagues, and organisational culture encourage or expect the use of a particular technology. In professional environments, these social pressures can significantly shape behavioural intentions and adoption decisions.

Personal innovativeness, on the other hand, reflects an individual's willingness to experiment with and adopt new technologies. Individuals with higher levels of innovativeness are more likely to embrace digital learning platforms and adapt to technological changes more readily. These individuals often act as early adopters, facilitating the diffusion of innovation within organisations.

While IDT provides a strong macro-level explanation of how innovations spread within social systems, it does not fully capture the internal cognitive processes that influence whether individuals translate external influences into actual behaviour. This limitation highlights the need to integrate complementary theoretical perspectives.

Social Cognitive Theory

Social Cognitive Theory (Bandura, 1997) explains human behaviour as a result of the dynamic interaction between personal factors, environmental influences, and behavioural outcomes. A central construct of SCT is self-efficacy, defined as an individual's belief in their capability to perform specific tasks successfully.

Self-efficacy plays a critical role in shaping behavioural intention, effort, persistence, and performance. In the context of e-learning, individuals with high self-efficacy are more likely to engage with digital learning platforms, overcome technical challenges, and sustain learning activities over time. Conversely, individuals with low self-efficacy may avoid using e-learning systems despite recognising their potential benefits.

Importantly, SCT provides a micro-level explanation of behaviour by emphasising cognitive mechanisms that mediate the relationship between external influences and actual actions. In

this study, self-efficacy is conceptualised as a mediating variable that translates the effects of social influence, cost-effectiveness, and personal innovativeness into e-learning adoption behaviour.

Theoretical Integration

The integration of IDT and SCT offers a more comprehensive explanation of e-learning adoption. While IDT explains how external social and individual factors drive initial adoption, SCT complements this by explaining how internal cognitive processes determine sustained engagement.

Specifically, social influence and personal innovativeness act as external and dispositional drivers of adoption, while cost-effectiveness introduces an economic evaluation dimension. However, these factors alone are insufficient to ensure behavioural outcomes. Self-efficacy serves as the critical mechanism that enables individuals to translate motivation into action.

By combining these theoretical perspectives, this study addresses the limitations of single-theory approaches and provides a holistic framework for understanding e-learning adoption in Industry 4.0 environments.

Literature Review

The adoption of e-learning in professional and organisational contexts has received increasing scholarly attention, particularly in response to rapid digital transformation under Industry 4.0. However, the adoption behaviour of engineers within manufacturing environments remains relatively underexplored. Existing literature suggests that technology adoption is influenced by a combination of social, economic, and individual cognitive factors. This section critically reviews the key determinants of e-learning adoption, namely social influence, cost-effectiveness, personal innovativeness, and self-efficacy, and examines their interrelationships in shaping sustained usage behaviour.

Social Influence and E-Learning Adoption

Social influence has been widely recognised as a significant determinant of technology adoption behaviour. Rooted in Innovation Diffusion Theory, social influence reflects the extent to which individuals perceive that important others such as supervisors, colleagues, and organisational culture encourage or expect the use of a particular technology.

Empirical studies consistently demonstrate that social environments play a critical role in shaping behavioural intention and usage. Raza et al. (2023) found that managerial encouragement significantly increases employees' willingness to adopt digital learning systems. Similarly, Al-Emran et al. (2023) reported that peer usage enhances perceived legitimacy and reduces uncertainty associated with new technologies. These findings suggest that social persuasion mechanisms can facilitate initial adoption by reinforcing normative expectations and reducing perceived risks.

In manufacturing environments, where teamwork and hierarchical structures are prevalent, social influence becomes particularly salient. Engineers are more likely to engage with e-learning when it is supported by leadership and embedded within organisational expectations. However, prior research also indicates that the impact of social influence may

diminish over time as individuals gain experience and develop independent evaluations of the technology. This suggests that while social influence is critical in the early stages of adoption, it may not be sufficient to sustain long-term engagement. Hence, this study posited that:
H1: Social influence has a positive effect on e-learning adoption

Cost-effectiveness and E-Learning Adoption
Cost-effectiveness represents a critical economic determinant influencing individuals' adoption of e-learning. It refers to the extent to which individuals perceive that the benefits of engaging in e-learning outweigh the associated costs, including time, effort, and financial investment. From a human capital perspective, individuals are more likely to participate in learning activities that enhance their productivity, skills, and career advancement (Becker, 1964).

E-learning platforms are widely recognised as cost-effective alternatives to traditional training due to their flexibility, scalability, and ability to minimise operational disruptions (Bond et al., 2023; Liao et al., 2023). In manufacturing environments, where continuous operations are essential, the ability to access training without interrupting production activities enhances the perceived value of e-learning.

However, adoption is not solely driven by objective cost savings but by individuals' subjective evaluation of value. When engineers perceive that e-learning contributes directly to job performance and professional growth, they are more likely to engage with such platforms (World Economic Forum, 2023). Conversely, if the perceived effort outweighs the benefits, adoption may be limited. Therefore, this study posits that:
H2: Cost-effectiveness has a positive effect on e-learning adoption.

Personal Innovativeness and E-Learning Adoption
Personal innovativeness refers to an individual's willingness to experiment with and adopt new technologies (Agarwal & Prasad, 1998). Within the context of Innovation Diffusion Theory, individuals with higher levels of innovativeness are more likely to act as early adopters and demonstrate a greater openness toward digital solutions.

Empirical studies have consistently shown that personal innovativeness significantly influences technology adoption behaviour, including e-learning systems (Dwivedi et al., 2023). Individuals who are more innovative tend to exhibit lower resistance to change, higher curiosity, and greater adaptability to emerging technologies.

In Industry 4.0 environments, engineers are required to continuously interact with advanced digital systems. As such, personal innovativeness becomes a critical capability that facilitates the exploration and adoption of e-learning platforms. Innovative individuals are more likely to perceive e-learning as an opportunity rather than a challenge.

However, while personal innovativeness encourages initial experimentation, sustained adoption may depend on additional factors such as cost and self-efficacy. Nonetheless, as an intrinsic trait, it plays a significant role in influencing adoption behaviour. Thus, this study proposes that:

H3: Personal innovativeness has a positive effect on e-learning adoption.

Social Influence and Self-Efficacy

Social influence not only affects behavioural intention but also plays a crucial role in shaping individuals' self-efficacy. According to Social Cognitive Theory, self-efficacy can be enhanced through social persuasion, observational learning, and encouragement from others (Bandura, 1997).

In organisational settings, support from supervisors and peers can strengthen individuals' confidence in their ability to use e-learning platforms. Observing colleagues successfully engaging with digital learning systems can reduce uncertainty and increase perceived capability. Similarly, encouragement from management can reinforce individuals' belief in their competence.

Empirical studies indicate that social environments significantly contribute to the development of self-efficacy in technology usage contexts (Al-Emran et al., 2023). In manufacturing organisations, where teamwork and hierarchical structures are prevalent, social influence can play a vital role in building confidence toward digital learning adoption. Therefore, this study hypothesises that:

H4: Social influence has a positive effect on self-efficacy.

Cost-Effectiveness and Self-Efficacy

Cost-effectiveness can also influence self-efficacy by shaping individuals' motivation and willingness to engage with e-learning platforms. When individuals perceive that the benefits of e-learning justify the effort required, they are more likely to invest time and energy into learning activities, thereby enhancing their confidence through experience.

From a cognitive perspective, positive cost-benefit evaluations can reduce psychological resistance and increase engagement, which in turn strengthens self-efficacy. As individuals interact more frequently with e-learning systems and experience successful outcomes, their belief in their ability to use these platforms effectively improves (Compeau & Higgins, 1995).

In contrast, if individuals perceive e-learning as time-consuming or not worthwhile, they may avoid engagement, limiting opportunities to develop confidence and competence. This highlights the indirect role of cost-effectiveness in shaping cognitive readiness. Thus, this study proposes that:

H5: Cost-effectiveness has a positive effect on self-efficacy.

Personal Innovativeness and Self-Efficacy

Personal innovativeness is closely associated with self-efficacy, as individuals who are more open to new technologies are more likely to engage in exploratory behaviour and accumulate positive experiences. These experiences contribute to the development of confidence in using digital systems.

Innovative individuals tend to approach new technologies with curiosity rather than apprehension, which enables them to overcome initial challenges and build competence over

time. This aligns with Social Cognitive Theory, which suggests that mastery experiences are a key source of self-efficacy (Bandura, 1997).

Empirical research supports the relationship between personal innovativeness and self-efficacy, indicating that individuals with higher innovativeness exhibit stronger confidence in their ability to use technology (Yi et al., 2006). In the context of Industry 4.0, this relationship becomes particularly important as engineers must continuously adapt to new digital tools.
Accordingly, this study hypothesises that:
H6: Personal innovativeness has a positive effect on self-efficacy.

Self-efficacy and e-Learning Adoption
Self-efficacy is a fundamental determinant of behavioural outcomes in technology adoption. It reflects an individual's belief in their ability to successfully perform tasks using a specific system (Bandura, 1997).

In e-learning contexts, individuals with high self-efficacy are more likely to engage with digital platforms, persist in the face of challenges, and achieve desired learning outcomes. Conversely, individuals with low self-efficacy may avoid using e-learning systems despite recognising their potential benefits.

Empirical studies consistently demonstrate that self-efficacy is a strong predictor of technology usage and sustained engagement (Yavuzalp & Bahcivan, 2022; Al-Emran et al., 2023). It influences not only initial adoption but also continued usage, making it a critical factor in long-term learning behaviour.

In Industry 4.0 environments, where digital learning systems can be complex, self-efficacy becomes even more important. Engineers must feel confident in their ability to navigate and utilise these platforms effectively. Therefore, this study posits that:
H7: Self-efficacy has a positive effect on e-learning adoption.

Mediating Role of Self-Efficacy
Beyond its direct effect, self-efficacy is proposed to mediate the relationships between social influence, cost-effectiveness, personal innovativeness, and e-learning adoption.

While external and individual factors may create favourable conditions for adoption, they do not guarantee behavioural outcomes. Self-efficacy explains how these factors are internalised and translated into actual engagement. Individuals are more likely to act on social encouragement, perceived value, and innovative tendencies when they possess sufficient confidence in their ability to use e-learning systems.

Self-efficacy functions as a central mediating variable that bridges the gap between external influences and behavioural outcomes. According to Bandura (1997), individuals are more likely to engage in a behaviour when they believe they possess the capability to perform it successfully. In the context of e-learning, self-efficacy determines whether engineers feel confident in their ability to use digital platforms, overcome technical challenges, and sustain engagement over time.

Importantly, self-efficacy is not formed in isolation but is influenced by external and individual factors. Social influence can enhance self-efficacy through encouragement, support, and observational learning. Cost-effectiveness can increase individuals' willingness to invest effort, leading to mastery experiences that strengthen confidence. Similarly, personal innovativeness promotes exploratory behaviour, allowing individuals to gain positive experiences with technology that further reinforce self-efficacy. These relationships highlight that self-efficacy acts as the psychological mechanism through which external drivers are internalised.

Furthermore, self-efficacy plays a decisive role in determining sustained e-learning adoption. While initial adoption may be influenced by social pressure or perceived value, long-term engagement depends on individuals' confidence in their ability to use the system effectively. This is particularly relevant in Industry 4.0 environments, where digital learning platforms are often complex and require continuous interaction. Without sufficient self-efficacy, individuals may discontinue usage despite recognising the benefits of e-learning.

The integration of these variables suggests that e-learning adoption is not a linear process but a multi-stage behavioural phenomenon. External factors such as social influence and cost-effectiveness, together with individual traits such as personal innovativeness, shape initial motivation and intention. However, the translation of these factors into actual and sustained behaviour depends largely on self-efficacy as a cognitive enabler. Therefore, the following mediation hypotheses are proposed:

H8: Self-efficacy mediates the relationship between social influence and e-learning adoption
H9: Self-efficacy mediates the relationship between cost-effectiveness and e-learning adoption
H10: Self-efficacy mediates the relationship between personal innovativeness and e-learning adoption

Conceptual Framework Development

Building upon the theoretical foundations and integrated discussion, this study proposes a conceptual framework to explain e-learning adoption among engineers in Malaysia's manufacturing sector within the context of Industry 4.0. The framework is grounded in the integration of Innovation Diffusion Theory (IDT) and Social Cognitive Theory (SCT), combining external influences, individual traits, and internal cognitive mechanisms into a unified model.

Unlike prior studies that examine technology adoption from a single perspective, this framework adopts a multidimensional approach by incorporating social, economic, and psychological determinants. Specifically, social influence, cost-effectiveness, and personal innovativeness are positioned as key antecedents, while self-efficacy is conceptualised as a mediating variable that translates these determinants into e-learning adoption behaviour.

The framework recognises that adoption is not an automatic outcome of external conditions. Instead, it is the result of a cognitive evaluation process in which individuals assess social expectations, perceived value, and their own capabilities before engaging with e-learning platforms. Figure 1 shows the interaction between all study variables that proposed the development of conceptual framework.

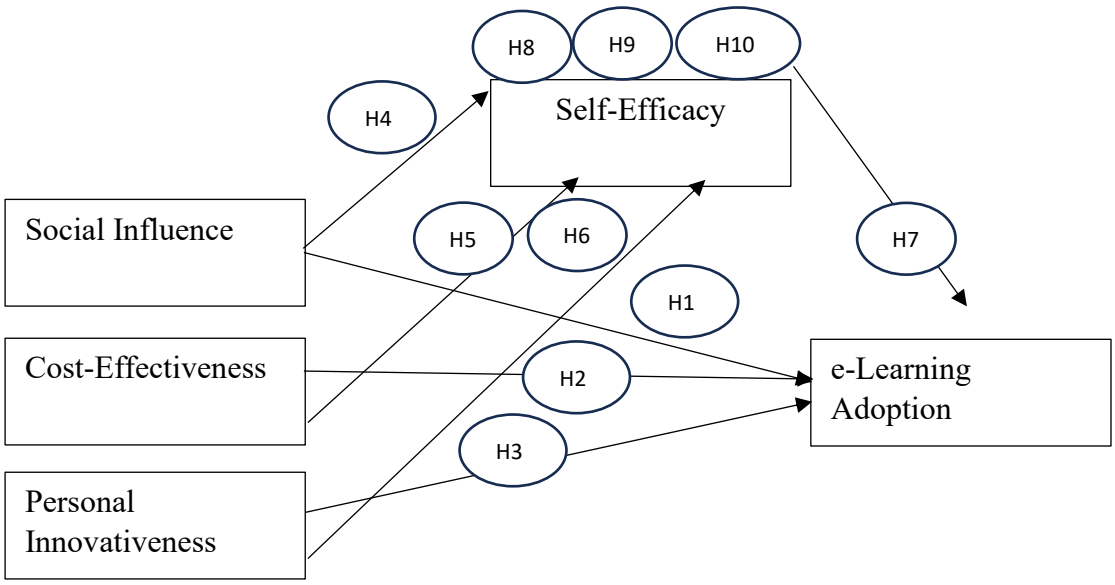

Figure 1: Conceptual Framework

Conclusion, Implications, and Future Research

This study set out to develop a comprehensive conceptual framework to explain e-learning adoption among engineers in Malaysia's manufacturing sector within the context of Industry 4.0. By integrating Innovation Diffusion Theory and Social Cognitive Theory, the study provides a holistic perspective that captures both external determinants and internal cognitive mechanisms influencing adoption behaviour.

The findings suggest that e-learning adoption is a multidimensional process shaped by the interaction of social, economic, and individual factors. Social influence plays a crucial role in establishing normative expectations and encouraging initial engagement, particularly in organisational environments where leadership and peer support are influential. Cost-effectiveness contributes to the evaluation of perceived value, influencing whether individuals consider e-learning to be a worthwhile investment of time and effort. Personal innovativeness reflects an individual's openness to new technologies and facilitates early adoption behaviour.

However, the study highlights that these factors alone are insufficient to ensure sustained e-learning adoption. Self-efficacy emerges as a critical mediating mechanism that determines whether individuals translate external influences and perceived value into actual behavioural outcomes. Engineers with higher levels of self-efficacy are more likely to engage with digital learning platforms, persist in the face of challenges, and achieve meaningful learning outcomes. Conversely, low self-efficacy can hinder adoption even when favourable external conditions exist.

Theoretical Implications

This study contributes to the literature by integrating Innovation Diffusion Theory and Social Cognitive Theory into a unified framework for understanding e-learning adoption. While prior research has often examined these theories independently, this study demonstrates the value of combining macro-level and micro-level perspectives to explain complex behavioural phenomena.

The study extends Innovation Diffusion Theory by incorporating cognitive mechanisms, particularly self-efficacy, as a mediator rather than treating adoption as a purely socially driven process. At the same time, it enhances the application of Social Cognitive Theory by positioning self-efficacy as a central mechanism that links external determinants to behavioural outcomes in digital learning environments.

Furthermore, this research shifts the focus from initial technology adoption to sustained engagement, addressing a critical gap in the literature. By emphasising the role of psychological readiness, the study provides a more nuanced understanding of long-term e-learning utilisation in professional contexts.

Managerial Implications

From a managerial perspective, the findings highlight that successful implementation of e-learning initiatives requires more than the provision of digital platforms. Organisations must create a supportive learning environment that encourages continuous professional development.

First, organisations should leverage social influence by fostering a culture that promotes learning through leadership support, peer collaboration, and recognition of learning achievements. Embedding e-learning within organisational expectations can enhance participation and normalise continuous learning practices.

Second, enhancing employees' self-efficacy should be a strategic priority. Organisations can achieve this by providing structured training programmes, user-friendly platforms, and continuous technical support. Opportunities for guided learning, mentoring, and hands-on experience can help build confidence and improve engagement with digital learning systems.

Third, organisations must ensure that e-learning initiatives are perceived as cost-effective by aligning learning content with job requirements and career development pathways. Practical, relevant, and outcome-oriented training programmes are more likely to sustain engagement among engineers.

Finally, organisations should identify and empower individuals with high levels of personal innovativeness to act as change agents. These individuals can facilitate knowledge sharing, encourage adoption among peers, and contribute to building a learning-oriented organisational culture.

Policy Implications

The findings also offer important insights for policymakers involved in workforce development and Industry 4.0 initiatives in Malaysia. While national strategies have emphasised technological advancement, equal attention must be given to human capital development and behavioural readiness.

Policymakers should support the development of accessible and cost-effective e-learning ecosystems, particularly for small and medium enterprises (SMEs) that may face resource constraints. Incentives such as subsidies, tax benefits, and shared digital learning platforms can encourage wider adoption.

In addition, national initiatives should focus on promoting a culture of lifelong learning through awareness campaigns and industry collaboration. Establishing standardised frameworks for digital skills certification can further enhance the credibility and value of e-learning programmes.

Importantly, policy interventions should also address psychological barriers to adoption by supporting programmes that build digital confidence and self-efficacy among the workforce. This human-centric approach is essential for ensuring the long-term success of digital transformation initiatives.

Contributions of the Study

This study offers a meaningful contribution by bringing together different perspectives to better explain how engineers actually adopt e-learning in real working environments. Rather than looking at adoption as a straightforward outcome of technology availability or organisational support, this research shows that what truly matters is how individuals interpret and respond to these influences internally. By combining Innovation Diffusion Theory and Social Cognitive Theory, the study provides a clearer explanation of how external factors such as social expectations, perceived value, and individual openness to innovation are translated into actual behaviour through self-efficacy. In doing so, it adds depth to existing models of technology adoption by highlighting that confidence in one's ability is not just a supporting factor, but a key driver of sustained engagement.

In terms of context, this research focuses on engineers in Malaysia's manufacturing sector, where continuous learning is increasingly critical due to rapid technological changes under Industry 4.0. Unlike many studies that concentrate on students or general employees, this study reflects the realities of engineers who operate in demanding, production-driven environments where time, cost, and practicality strongly influence learning decisions. By capturing this setting, the study provides insights that are more grounded and relevant to industry practice. It emphasises that successful e-learning adoption is not only about providing platforms, but also about building confidence, aligning learning with job needs, and creating an environment that supports ongoing development. As such, the study contributes to a more practical and context-sensitive understanding of how digital learning can support workforce sustainability in modern manufacturing industries.

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