

INDUSTRY 4.0 PREPAREDNESS: AN EMPIRICAL STUDY OF DIGITAL LITERACY AND EMPLOYEE PERFORMANCE IN THE MANUFACTURING SECTOR OF A DEVELOPING ECONOMY

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Abstract

Within the concept of Industry 4.0, this paper analyzes the level of digital literacy of employees of the manufacturing industry in Gujranwala, Pakistan, with the view of determining how the technological, organizational, and environmental circumstances affect digital competence and readiness to digital transformation. The survey was conducted using a well-organized questionnaire that was administered by means of random sampling of 178 manufacturing employees in accordance with the Technology-Organization-Environment (TOE) scheme. Partial Least Squares Structural Equation Modeling (PLS-SEM) was used to analyze the data manually through Smart PLS-4 to guarantee clarity and accuracy. The outcome revealed rather high rates of digital literacy in technological (DLT = 4.30), organizational (DLO = 4.35), and environmental (DLE = 4.33) settings. A slightly lower correlation was, however, identified between the influence of digital literacy on the employee performance (DLEP = 3.95). The constructs possessed a high level of internal consistency and convergent validity which confirmed the usefulness of the TOE framework in assessing digital readiness. The paper recommends that companies seeking to improve their level of technological adaptation ought to deploy job role-focused digital learning programs and perform a digital literacy audit. Digital literacy tests should be implemented into the recruitment processes and performance management systems utilized by human resource policies, and the old-fashioned performance indicators need to be changed into digital KPIs. The study is one of the few research works on digital transformation in the manufacturing industry in the Gujranwala region, which will provide practical recommendations on upskilling industrial workers in developing economies.

INTRODUCTION

With the advent of the era of the Fourth Industrial Revolution (Industry 4.0), the introduction of digital technologies into the organizational process has ceased to be a strategic advantage and has become a crucial obligation. Digital transformation is no longer an option but a necessity when manufacturing firms attempt to keep up with the fast-paced markets

and endeavor to remain competitive (Thummasena et al., 2024). This change does not just concern the introduction of advanced equipment in the forms of automation, artificial intelligence (AI), and Internet of Things (IoT) devices but also requires a digitally skilled labor force that knows how to use these new tools to an advantage. In the absence of a sufficiently

skilled human resource base, investment in digital technologies might not bring the desired changes in productivity, innovation and sustainable growth.

The concept of digital literacy here implies how well the employees can use digital tools, understand digital information, and collaborate and innovate using technology as the driving force. It runs across technical expertise, critical thinking, and the ability to adjust with new technologies. Researchers believe that the effectiveness of digital programs in the manufacturing industry is closely associated with digital talent among the laborers. Whether it is running computer-aided design (CAD) systems or enterprise resource planning (ERP) systems, workers need to be capable of handling both the technical and cognitive aspects of digital literacy to help achieve operational efficiency and constant improvement.

Although the critical importance of digital competence has been acknowledged, a large number of organizations, especially those in the developing nations do not have a precise and in-depth idea on the level of digital literacy of their employees. This information black hole makes it difficult to plan and introduce specific upskilling measures. According to the measurement of digital literacy at the workplace is a complex issue, and it depends on many factors, including age, education, training possibilities, and organizational culture. In addition, there is no digital competence uniformity between various departments or job positions within an organization. There are workers who can easily orient themselves in specialized software, and there are those who have difficulty with simple means of digital communication. In this way, existing competencies and deficiencies should be perceived with a high level of nuance to design effective interventions. The shift toward digitization of the processes is a problem and an opportunity in the context of the Pakistani manufacturing sector, in which many facilities still rely on the traditional methods of production. This is the case with the manufacturing sector of Gujranwala, one of the major industrial centers of Punjab province of Pakistan. With the companies of this area starting to scale and onboard more digital systems in their processes, it is of high importance to evaluate the preparedness of their human resources to such change. In the absence of this knowledge,

these organizations face the risk of underutilizing their investments in technology and also missing out on innovation, efficiency and competitiveness (Cheema, 2025a).

Thus, the proposed research attempts to fill this gap in knowledge by logically examining the digital literacy of the employees that are employed in the manufacturing sector of Gujranwala. The study is centered on three fundamental dimensions technical competence in digital tools employed in the manufacturing, information literacy (i.e. the capacity to read and apply digital information), and engagement in digital innovation and collaboration. In this way, the research aims to contribute a statistically grounded basis of the creation of individual training plans and HR development policy.

2. Literature Review:

Digital literacy is an emerging concept in the research on manufacturing and Industry 4.0 due to the fact that the importance of digital literacy has been boosted to a pivotal status due to the integration of automation, data analytics, and smart technologies into the industrial landscape (Ismail & Hassan, 2019; Saari et al., 2021). In this environment, scholars are examining aspects of digital literacy, including technical aptitude, information-processing skills and innovation in collaboration to see their effects in organizational change and productivity.

Technical Proficiency in Digital Tools

The digital literacy in manufacturing revolves around technical competence. In addition to basic digital literacy, workers are required to be adept with dedicated systems such as Computer-Aided Manufacturing (CAM), Supervisory Control and Data Acquisition (SCADA), and predictive maintenance platforms. Studies have shown that insufficient digital training on these industry-specific systems negatively impacts workforce performance and suppresses innovation (Miah et al., 2024). Companies that have implemented structured digital-skills training programs report measurable gains in precision, work-process efficiency, and faster problem resolution (Eversberg & Lambrecht, 2023; Ipsita et al., 2025).

In Gujranwala, Pakistan, qualitative research highlights a significant barrier to Industry 4.0: the absence of structured digital training. Many workers underutilize advanced systems due to limited technical knowledge, with some explicitly resisting change as they fail to grasp the full potential of such technology (Hussain, 2021; Miah et al., 2024).

Information Literacy and Decision-Making

Information literacy—the ability to locate, interpret, and utilize electronic data—is crucial in modern manufacturing environments. As digital systems proliferate data, employees must derive actionable insights from dashboards, reports, and analytic platforms. Researchers emphasize that employees' capacity to analyze and act on real-time data is fundamental to successful digital transformation (Safi, Abdallah, Erturk, & Alkhayyat, 2024).

A deficiency in information literacy can lead to missed opportunities or operational errors, especially when employees overly rely on supervisors to interpret data (Ahmad, Widén, & Huvila, 2020). Though no specific studies exist for Gujranwala, analogous research in similar industrial contexts shows that lacking information literacy integration into daily workflows hampers responsiveness and overall efficiency (Naveed, Asif, & Awan, 2021). These insights align with broader evidence suggesting that digital ecosystems require context-specific data capabilities for full operational integration (Safi et al., 2024).

Digital Innovation and Collaboration

Digital literacy in smart manufacturing incorporates digital collaboration and innovation as core elements. Cross-functional teams accelerate product development and reduce time-to-market through real-time communication tools, shared documentation, and online brainstorming platforms (Ahmad, Boit, & Aakula, 2021; McKinsey & Company, 2022). Embedding collaboration directly into workflows—such as root-cause investigations and maintenance—enables quicker decision-making and improves KPIs like uptime and quality (McKinsey & Company, 2022). Studies indicate that while some firms in Gujranwala have begun adopting digital collaboration, a pervasive culture of collaborative innovation remains undeveloped (Abdalla &

Nakagawa, 2021). At a macro level, both healthcare and industrial sectors face similar challenges—namely institutional inertia and insufficient digital readiness—echoing insights from frameworks like ORC and TAM (McKinsey & Company, 2022).

Institutional and Contextual Readiness

Training of skills is not enough in the adoption of digital literacy. As shown in a recent study of Swiss companies, organizational culture, in particular visionary leadership, prioritized resources, and a continuous learning attitude is an important factor in adopting Industry 4.0 technologies (Wiese, Lehmann, & Beckmann, 2024).

Finally, in the public healthcare setting of Gujranwala, discovered that digital and AI readiness were closely associated with the clear expression of the leadership vision, coherent policymaking, resource commitment, and engaged employee base (Cheema et al., 2025b). These insights are naturally relevant to healthcare, but they can be applied to manufacturing as well, where onboarding new hires with a dull attitude and inflexible old systems often spoil the digital plans. Wide organizational readiness, culturally flexibility, process conformity, and cyber competence are therefore critical in the ongoing Industry 4.0 incorporation.

Synthesis and Research Gap

The analyzed literature supports the view that digital literacy in manufacturing is multidimensional and technically cannot be reduced only to a set of technical skills but also penetrating and working with digital information, as well as collaboration in digital space. Nonetheless, the literature has a dearth of sector-specific, local area insights about workforce digital literacy, particularly about the industrial powerhouses such as Gujranwala. The papers by Cheema et al. (2025a, 2025b) help to address this gap considerably, yet they also show that more profound, ongoing evaluations are needed at the firm level. The research is therefore aimed at providing practical recommendations on the current level of digital competency among the manufacturing employees in Gujranwala, as a way of informing effective training and transformation programs

3. Theoretical Framework:

The theoretical frame work we are going to use for this research is TOE framework (Technology-organization-environment framework) (Eze, et al., 2023; Mohd Abas et al., 2019). This framework is a theoretical construct that provides an explanation of technology adoption in organizations in the technological, organizational, and environment

context, impact the adoption and implementation process of technological innovations. This model was developed in 1990 by Fleischer and Tornatzky. The TOE framework is in context to measure digital literacy level of employees for the a manufacturing industry so that we can analyze the future problem we might face while adopting new technologies.



Fig 3.1: The TOE Framework

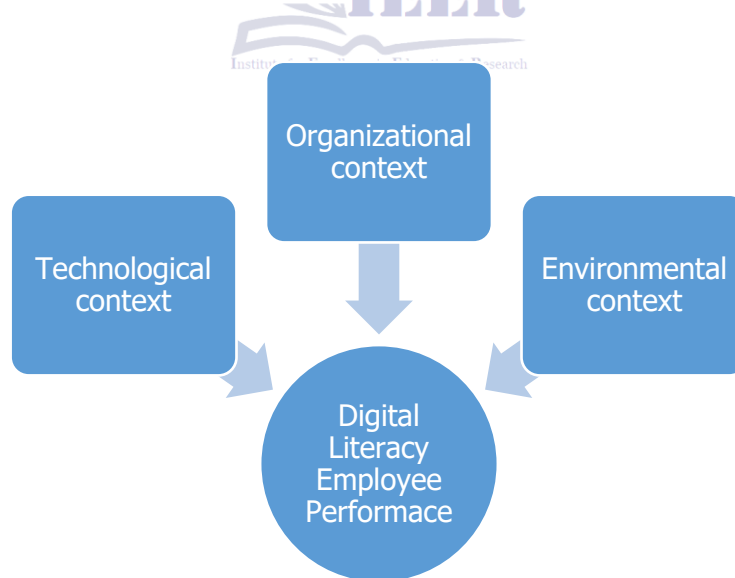


Fig 3.2 Relationship between TOE and digital literacy level

4. Sample & Population:

The target audience for this study was employees of a manufacturing sector of Gujranwala. A randomized sampling technique was applied to ensure

representation from a range of departments, roles, and responsibilities. By doing this, as opposed to focusing on a specific subset, the research seeks to

acquire a comprehensive image of the levels of digital literacy across the entire enterprise.

To collect data, the research printed the questionnaire and get this data by directly approaching to the employees as it was the primary

data and the accuracy of data is very important, secondly most of the employees might not able to reach the real essences of this questionnaire so for that reason too data was collected manually.

Table 1: Demographic

Construct	Category	Frequency	Percentage (%)
Gender	Male	139	78.90
	Female	39	21.10
Age	Up to 25	35	19.66
	26-45	117	65.73
	46+	10	5.62
Education	Matric	11	6.20
	Intermediate	29	16.30
	Bachelor	86	48.30
	Master	50	28.10

Results Table 1 shows the demographic characteristics of the sample. The table shows the number of participants on the basis of age, gender and education. Table represents that male respondents were 139 (78.90%), female respondent was 21.10%, the respondents age up to 25 years old were 35 (19.66%), 26-46 years response rate was 117 (65.73%) and 10 (5.62%) response rate from 46+ years old. The respondent response rate according to education level Matric 11(6.20%), Intermediate 29(16.03%), Bachelor 86(48.30%) and Master 50(28.10%).

5. Instrumentation:

The primary instrument for data collection was a structured questionnaire. The carefully thought-out design of this questionnaire was built upon the modified TOE Framework (Digital literacy Context). The questionnaire consisted on Likert-scale format in order to quantitatively assess respondents' levels of digital literacy in the areas of technological Context.

The questionnaire was adopted from Mohd Abas et al., 2019.

A comprehensive statistical analysis was conducted on the data collected from the survey. The analytical approach that facilitated the extraction of significant insights allowed for a more sophisticated understanding of the digital literacy landscape inside the manufacturing organization.

6. Results

This study focused on the partial least square structural equation modeling (PLS-SEM) technique and examined variables and hypotheses using Smart PLS-4 statistical software. The program is regarded as a contemporary measurement tool with a trustworthy estimate technique and is widely utilized in research (Ali et al. 2018; Ringle et al. 2005).

According to Hair et al. (2016), PLS-SEM is a well-liked option because of its simplicity and low data needs.

Table 2: Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
DLT	178	1	5	4.30	0.89
DLO	178	1	5	4.35	0.88
DLE	178	1	5	4.33	0.90

DLEP	178	1	5	3.95	0.95
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Table 2 represents the descriptive statistics including range, mean and standard deviation. The "N" column shows the number of observations for each construct. Table describes that there was 178 observations or responses for each of the four constructs. The "mean" value represents the average or arithmetic mean values for each construct. It represents the dataset's core trend. Similarly, the

average value for "DLT" was 4.30, "DLO" was 4.35, "DLE" was 4.33 and "DLEP" 3.89. The "Std. deviation" measures the data's dispersion or variability around the mean. A higher standard deviation indicates greater variability in the scores. Additionally, the SD for the "DLT" was 0.89, "DLO" was 0.88, "DLE" was 0.90 and for "DLEP" was 1.02.

Table 3: Correlation Analysis

Variables	DLT	DLO	DLE	DLEP
DLT	1	.751	.751	.217
DLO	.751	1	.797	.254
DLE	.751	.797	1	.293
DLEP	.217	.254	.293	1

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3 shows the correlation analysis is an important step in establishing the level of relationship between two categorical variables as illustrated below: -

It investigated internal reliability, convergent validity (CV), and discriminant validity (DV). The results of

the measurement model evaluation shows that the study's constructs have a sufficient level of internal consistency because the values of the CR (0.88), CFC-I (0.95), AVE value 0.59, career optimism (0.93), and Alpha value 0.88 are significantly higher than the threshold values (0.70).

Table 4: Convergent validity

Constructs	Items	Loading	Alpha	CR	AVE
Digital Literacy Technological Context	DLT1	.443	.755	.881	.30
	DLT2	.395			
	DLT3	.640			
	DLT4	.447			
	DLT5	.578			
	DLT6	.452			
	DLT7	.782			
	DLT8	.562			
	DLT9	.586			
	DLT10	.526			
Digital Literacy Organizational Context	DLO1	.673	.724	.744	.346
	DLO2	.590			
	DLO3	.624			
	DLO4	.536			
	DLO5	.310			
	DLO6	.643			
	DLO7	.633			
	DLO8	.616			

Digital Literacy Environmental Context	DLE1	.461	.729	.720	.333
	DLE2	.630			
	DLE3	.722			
	DLE4	.633			
	DLE5	.596			
	DLE6	.550			
	DLE7	.515			
	DLE8	.459			
Digital Literacy Employee Performance	DLEP1	.216	.532	.397	.195
	DLEP2	.655			
	DLEP3	.131			
	DLEP4	.329			
	DLEP5	.059			
	DLEP6	.624			
	DLEP7	.633			
	DLEP8	.406			

Table 4 shows convergent validity data for alpha and reliability (CR) values, with findings indicating that an alpha value of 0.88 and a CR value of 0.88 for each concept were judged satisfactory (Hair et al.

2014). Furthermore, the AVE value for each construct was evaluated; the results revealed that the AVE value of 0.594 was greater than 0.50, which was deemed acceptable.

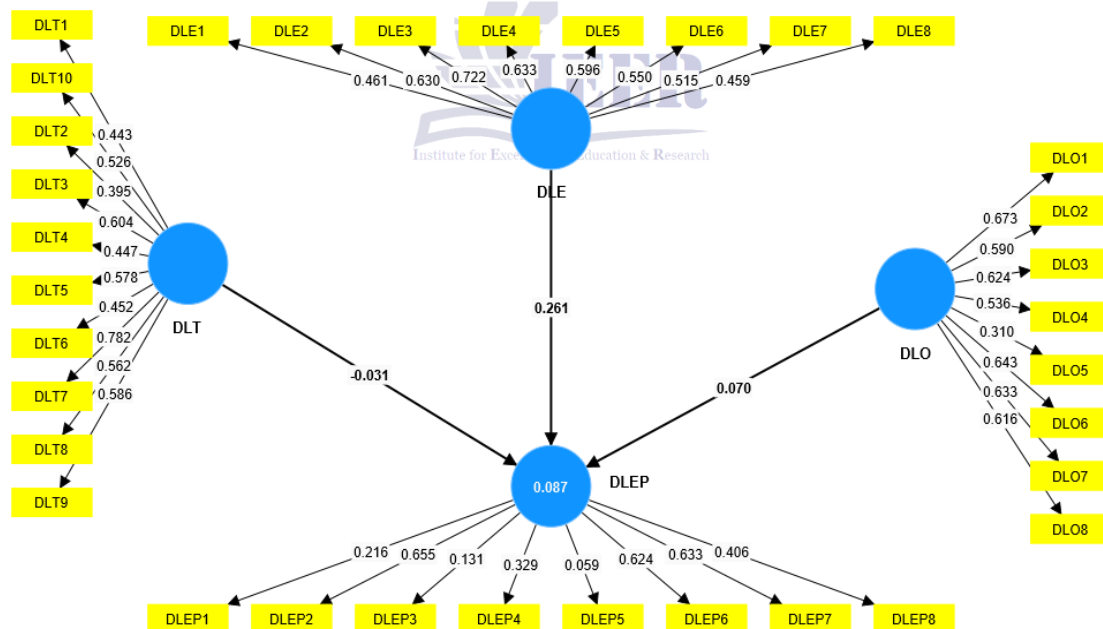


Figure 1: Measurement model assessment

We used the Heterotrait-Monotrait ratio to assess discriminant validity (as shown in Table 5), and Table 5 (Kline 2015) shows that all the constructs were significant as their results were below 0.85. It was confirmed through the research that the HTMT

ratio of the built projects is valid (Kline 2015). The study mainly depended on convergent and discriminant methods to check the validity and reliability of the measurement model. According to the results, the indicators of the model demonstrated

good validity and reliability (Hair et al. 2017, 2014; Cheung & Wang 2017; Kline 2015).

After checking the measurement model, it was determined that the constructs met expectations. All variables in the examined model had a Cronbach's alpha and composite reliability (CR) greater than 0.70 as suggested by Hair et al. (2014). The AVE values were higher than 0.50, proving that all variables are related to similar concepts. Both the Heterotrait-Monotrait (HTMT) ratio and the Fornell-Larcker criteria demonstrated that each factor is different from the rest.

7. Discussion

The findings of this paper offer useful information about the situation of digital literacy in the manufacturing industry of Gujranwala with reference to Industry 4.0. The results illustrate that staff members have quite good digital literacy in technological, organizational, and environmental settings since the mean scores in these dimensions are high. A significant gap however comes in when considering the relationship of such digital competencies with employee performance which yields less significant relationships and lower reliability indices. A high correlation among DLT, DLO, and DLE confirms prior studies indicating that successful digital literacy cannot be restrained to technical abilities but is facilitated by a facilitating organizational setting and cultural preparedness (Ismail & Hassan, 2019; Saari et al., 2021).

These dependencies confirm that digital literacy is a multidimensional construct and it is influenced by both personal abilities and institutional support structures. Regardless of these strong points, low reliability and validity were recorded in the Digital Literacy Employee Performance (DLEP) construct. A number of items performed poorly regarding factor loadings, and the values of Cronbach's Alpha and Composite Reliability were not at an acceptable level. It implies that digital competence of workers does not necessarily mean the objective increase in the quality of work, either—the finding that Ahmad, Boit, and Aakula (2020) also came to.

A useful model that was used in this TOE (Technology Organization Environment) research was the TOE framework. It has shown that Industry 4.0 digital literacy is not technologically spurred

only, but it is also influenced by organizational culture and environmental preparedness (Eze et al., 2023; Mohd Abas et al., 2019). This is consistent with the findings of Wiese, Lehmann, and Beckmann (2024) and Cheema et al. (2025) that spoke of the importance of leadership vision and policy support in facilitating a digital transformation.

8. Conclusion

The present study highlights the need to consider digital literacy as one of the necessities to realize Industry 4.0 in the developing economies. When it comes to Gujranwala manufacturing sector, moderate to high levels of digital literacy are displayed by employees in different settings, which means that there is a strong starting point that could be later used to perform technological upgrades. The inconsistency between digital literacy and perceived performance outcomes is, however, an indication that the measurement of digital contribution at individual levels should be reconsidered.

These findings have some important implications:

- Organizations ought to acquire customized digital training programs that surpass the fundamentals to performance-driven apps.
- HR departments ought to incorporate digital literacy tests in the recruitment, onboarding, and appraisal systems so that they can be in tandem with the strategic digital objectives.
- Policymakers and researchers ought to design superior measures of assessing digital dexterities in relation to performance, particularly in the conventional industries where organizations are restructuring to support smart-manufacturing operations.

9. Future Implications:

Further studies ought to perfect the DLEP construct, introduce longitudinal data and extend the sample to several industrial centers to allow comparative perspectives. In addition, real-life effects of digital literacy would be better understood by investigating its changes over time after training interventions. Conclusively, digital transformation is a complicated and multiple-layered competitive, innovative, and strong manufacturing institutions.

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