

RESEARCH ARTICLE

User-Centric Design Thinking Framework for Digital Transformation: Bridging the Digital Literacy Gap in Thai Manufacturing SMEs

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Abstract

While digital transformation is essential for enhancing the competitiveness of Small and Medium-sized Enterprises (SMEs), a significant barrier remains in the form of low levels of employees' digital literacy. This study addresses this critical challenge by proposing and validating a User-Centric Design Thinking Framework for developing digital tools in environments characterized by varying levels of technological proficiency. Using a Thai manufacturing SME as a case study, the study employed a five-stage Design Thinking process involving 20 participants to develop a web-based production management system. The methodology emphasized empathy and iterative feedback to ensure the system was intuitive, accessible, and aligned with user needs. Post-implementation analyses revealed substantial operational improvements, including an 81.1% reduction in production monitoring time and an 80.7% decrease in reporting time, accompanied by significant cost savings. Usability testing, incorporating both qualitative feedback and quantitative assessment, demonstrated a high level of user satisfaction (mean score = 4.52 out of 5). The findings indicate that a user-centric approach is effective in not only bridging the digital literacy gap but also enhancing business performance. This study provides a practical and replicable framework for technology adoption in SMEs and contributes to the broader understanding of inclusive digital transformation in developing economies.

1. Introduction

Digital transformation is a strategic imperative for the competitiveness of Small and Medium-sized Enterprises (SMEs), particularly in developing economies where SMEs constitute a major component of economic activity (Economic Research Institute for ASEAN and East Asia (ERIA) and Organisation for Economic Co-operation and Development (OECD), 2024). Although digital technologies provide substantial opportunities for improving operational efficiency, a fundamental barrier frequently hinders successful implementation: low levels of employee digital literacy. This challenge creates a significant disconnect in which employees possess extensive operational expertise but lack the digital competencies required to effectively utilize new technologies (Intaratat, 2022). Consequently, the issue extends be-

yond employee training and represents a critical design challenge, which forms the central focus of this study.

Despite extensive research on digital transformation, a specific research gap remains regarding the effective implementation of digital tools in SME environments characterized by limited digital literacy. Previous studies on technology adoption have often emphasized technical functionality rather than user accessibility or have been conducted in developed economies with different resource conditions. Although the potential of Design Thinking for addressing complex organizational challenges has been widely recognized (Rösch et al., 2023), empirical evidence demonstrating its effectiveness in bridging digital literacy barriers within manufacturing SMEs in developing countries remains limited. This study addresses this gap by focusing on the development of an accessible digital system designed specifically for users with limited digital experience rather than adapt-

ing existing technologies that may be difficult to use in such contexts.

To address this gap, this study proposes and validates a User-Centric Design Thinking Framework for the development and implementation of a web-based production management system in a representative Thai manufacturing SME. Through an in-depth case study, this study demonstrates how an empathy-driven and iterative design process can reduce digital literacy barriers while delivering substantial operational improvements. The contributions of this study are three-fold. First, it provides empirical evidence supporting a human-centered approach in low-digital-literacy environments, thereby extending current technology adoption research. Second, it establishes a practical and replicable framework that can guide SMEs facing similar challenges. Third, it validates Design Thinking as an effective methodology for achieving inclusive and impactful digital transformation.

2. Literature Review

This section reviews the literature relevant to this study and establishes its theoretical foundation. First, the challenges of digital transformation and technology adoption in SMEs are discussed, with particular attention given to the digital literacy gap. Second, Design Thinking is examined as a human-centered methodology for addressing organizational and technological challenges. Finally, usability principles and system design considerations for low-digital-literacy environments are reviewed.

2.1 The Challenge of Digital Transformation and the Digital Literacy Gap in SMEs

Digital transformation represents a fundamental organizational change process that enables enterprises to utilize digital technologies to improve efficiency, innovation, and competitiveness (Economic Research Institute for ASEAN and East Asia (ERIA) and Organisation for Economic Co-operation and Development (OECD), 2024). For SMEs, digital transformation is increasingly recognized as a strategic necessity; however, successful implementation is often constrained by limited organizational resources and inadequate workforce digital competencies (Faiz et al., 2024). Digital literacy extends beyond technical skills and includes the cognitive and behavioral capabilities required to effectively interact with digital technologies and information systems (Reddy et al., 2023).

Previous studies consistently identify low digital literacy as a major barrier to technology adoption in SME environments, often exerting a greater influence than financial or technological constraints (Faiz et al., 2024). This challenge is particularly evident in Thai SMEs, where employees frequently possess substan-

tial operational expertise but limited digital proficiency (Intaratat, 2022). Such conditions create significant implementation barriers that conventional technology-centered approaches and standard training programs may not adequately address. These limitations highlight the need for alternative approaches that prioritize user needs and accessibility throughout the system development process.

2.2 Design Thinking in Digital Transformation

Design Thinking has emerged as an effective methodology for addressing complex organizational and technological challenges through a human-centered approach to innovation (Benabderrazik et al., 2025). The framework commonly consists of five iterative stages: empathize, define, ideate, prototype, and test. These stages provide a structured process for understanding user needs, generating solutions, and continuously improving system designs based on user feedback.

Recent studies have demonstrated the value of Design Thinking in supporting organizational transformation and technology adoption. Rahman and Jyoti (Rahman and Jyoti, 2022) reported that user-centered design approaches improve stakeholder engagement, system accessibility, and organizational acceptance during digital transformation initiatives. Similarly, Rösch et al. (Rösch et al., 2023) highlighted the importance of empathy-driven design processes in developing solutions that align with user expectations and organizational objectives. These findings support the application of Design Thinking as a suitable methodological framework for addressing digital literacy challenges in SME environments. Nevertheless, empirical evidence remains limited regarding its implementation within manufacturing SMEs in developing countries, particularly where users possess minimal digital experience.

2.3 Usability and System Design for Low-Digital-Literacy Users

Usability plays a critical role in determining whether digital systems can be effectively adopted by users with limited technological experience. According to ISO 9241-11, usability refers to the extent to which specified users can achieve specified goals with effectiveness, efficiency, and satisfaction in a particular context of use (International Organization for Standardization, 1998). For users with low digital literacy, system usability becomes particularly important because complex interfaces and unintuitive workflows can significantly hinder technology adoption.

User-centered design principles emphasize the importance of understanding user characteristics, capabilities, and limitations throughout the system development lifecycle (Rahman and Jyoti, 2022). Previous studies have shown that accessible interfaces, simpli-

fied workflows, and iterative user feedback can improve technology acceptance and reduce barriers to system adoption. In SME environments, where employees often possess diverse levels of digital proficiency, usability-oriented design approaches can facilitate successful technology implementation by aligning system functionality with user capabilities.

These findings suggest that successful digital transformation requires more than technological innovation alone. Effective implementation depends on designing systems that accommodate user needs, digital literacy levels, and workplace contexts. This perspective provides the theoretical foundation for the user-centric Design Thinking framework proposed in this study.

3. Research Methodology

This study employed a qualitative case study approach based on a five-stage Design Thinking framework to develop and implement a production management system in a representative Thai manufacturing SME. The methodology was selected because of its effectiveness in addressing complex human-centered challenges and supporting solution development through continuous user engagement and iterative refinement.

3.1 Research Framework: The Design Thinking Process

The study was structured around the five-stage Design Thinking framework consisting of empathize, define, ideate, prototype, and test. This framework provides a systematic approach for understanding user needs, generating solutions, and refining system designs through iterative feedback. Figure ?? illustrates the overall research framework adopted in this study.

The activities performed in each stage are summarized as follows:

1. **Empathize:** User experiences, operational challenges, and workplace contexts were investigated through direct observation and in-depth interviews.
2. **Define:** Information collected during the empathize stage was synthesized to formulate a clear problem statement reflecting user needs and operational requirements.
3. **Ideate:** Potential solutions were generated through structured brainstorming sessions that encouraged creative thinking and alternative perspectives.
4. **Prototype:** A low-fidelity interactive prototype of the proposed web-based production management system was developed. The prototype was implemented using the Laravel framework to support rapid and iterative development.
5. **Test:** Users evaluated the prototype through structured testing scenarios and usability assessments. Feedback obtained during this stage was used to improve subsequent versions of the system.

3.2 Case Study and Participant Selection

Purposive sampling was employed to select a representative Thai manufacturing SME, Chiang Mai Parts and Tools Co., Ltd., and twenty participants. The company was selected because it represents a medium-sized manufacturing enterprise experiencing digital literacy challenges while operating relatively complex production processes.

The participant group was intentionally composed to represent different organizational roles and levels of digital proficiency. The participants included two managers, two production supervisors, two planning officers, and fourteen production workers. This distribution enabled the collection of diverse perspectives ranging from strategic management requirements to day-to-day operational needs.

3.3 Usability Evaluation Framework and Data Analysis

A mixed-methods approach was adopted to evaluate system usability and user satisfaction. Qualitative and quantitative data were collected to provide a comprehensive assessment of the proposed system.

3.3.1 Justification of Evaluation Criteria

The usability evaluation framework was developed based on the principles of effectiveness, efficiency, and user satisfaction defined in ISO 9241-11 (International Organization for Standardization, 1998). Six evaluation items were used to assess usability, system functionality, and graphical user interface design, as presented in Table 1. These criteria were selected to ensure that the evaluation adequately reflected the needs of users with varying levels of digital literacy while maintaining consistency with established usability standards.

3.3.2 Data Analysis

Qualitative data were collected through open-ended feedback associated with each evaluation criterion. The responses were analyzed to identify user perceptions, strengths of the proposed system, and opportunities for improvement.

Quantitative data were collected using a six-item questionnaire based on a five-point Likert scale, where 1 represented ‘Strongly Disagree’ and 5 represented ‘Strongly Agree.’ Mean scores were calculated to summarize user satisfaction and perceived usability. The

Table 1. Evaluation items.

Evaluation Criteria	Questions
System meets the user's	Q1. Practical use, easy to use, and quick to understand.
Requirements (usability)	Q2. Appropriate design for the user.
Use of system functions	Q3. Provides precise and reliable results. Q4. Compatibility between main functions and the user interface menu.
Graphic user interface	Q5. Design menus, buttons, colors, and fonts are easy for all users. Q6. Appropriate screen size and visibility.

integration of qualitative feedback and quantitative assessment provided a comprehensive evaluation of system effectiveness and strengthened the credibility of the study findings.

4. Results

This section presents the findings of the study following the five-stage Design Thinking process. The results from each stage are presented sequentially, followed by usability evaluation outcomes, operational performance improvements, and an analysis of the impact of Design Thinking on technology adoption and organizational outcomes.

4.1 Results of the Empathize Stage

The empathize stage focused on obtaining a comprehensive understanding of user requirements and the operational challenges associated with production monitoring and resource management. Through observations and interviews, several critical issues were identified. Participants reported difficulties in tracking production orders, monitoring production progress, and evaluating the utilization of machines, personnel, and materials.

The findings indicated a strong need for a web-based production management system capable of providing real-time monitoring of production activities, rapid access to operational information, and convenient accessibility through mobile devices. Participants emphasized the importance of immediate access to production data to support decision-making and improve operational coordination.

Effective production management requires accurate and timely data collection to facilitate resource planning and production capacity monitoring (Rácz-Szabó et al., 2020). Therefore, the proposed system was designed to support real-time information management and improve visibility throughout the production process.

4.2 Results of the Define Stage

The findings obtained during the empathize stage were synthesized and transformed into a set of clearly defined user requirements. The identified requirements were categorized into three major groups corresponding to production monitoring, resource management, and reporting functions. These requirements served as the foundation for subsequent ideation and system design activities. The complete set of requirements is summarized in Table 2.

4.3 Results of the Ideate Stage

The ideate stage focused on generating potential solutions capable of addressing the challenges identified during the previous stages. A collaborative brainstorming process involving managers, supervisors, planning officers, and production workers was conducted to ensure that diverse perspectives were incorporated into the system design.

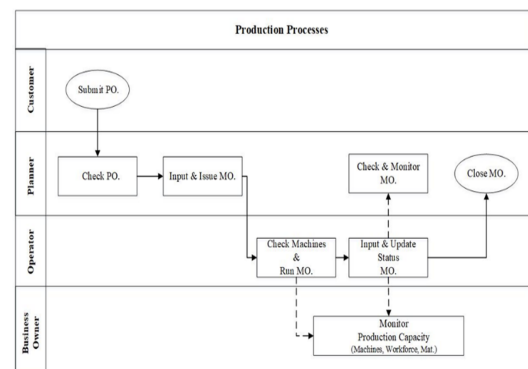


Figure 1. The swim lane diagram of production processes.

Table 2. Main requirements for the development of a system.

Problems	Solution
Cannot monitor real-time production orders for individual customers.	Create a function for real-time monitoring of production orders separated by customer.
Difficulty in evaluating workforce and machinery capacity.	- Provide a function that allows planning officers to assign employees to workstations or machinery. - Create a real-time dashboard showing employee performance at each workstation. - Create a real-time dashboard displaying workstation capacity, including machinery and workforce utilization.
Delays in raw-material purchasing and customer response activities.	- Develop an online platform that is accessible from various mobile devices. - Provide an easy-to-use system that allows owners and planning officers to make timely raw-material purchasing decisions based on real-time production capacity information. - Enable users to access the system anytime and anywhere to quickly monitor order status and communicate updates to customers.

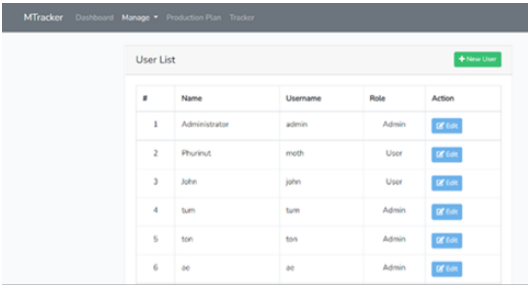


Figure 2. The screens shot of a functioning user and list of user roles in web-application system.

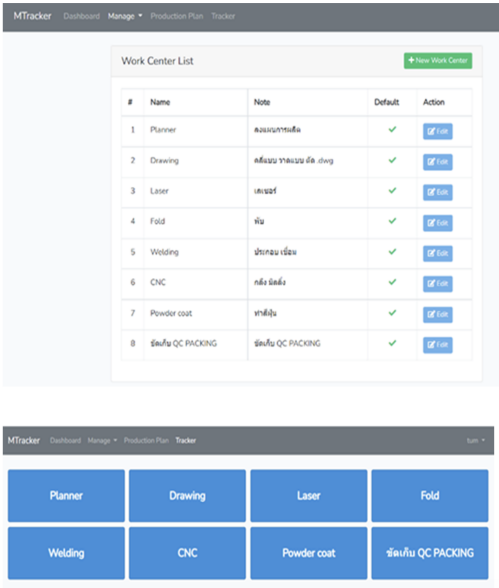


Figure 3. The screens shot for function input work center and details.

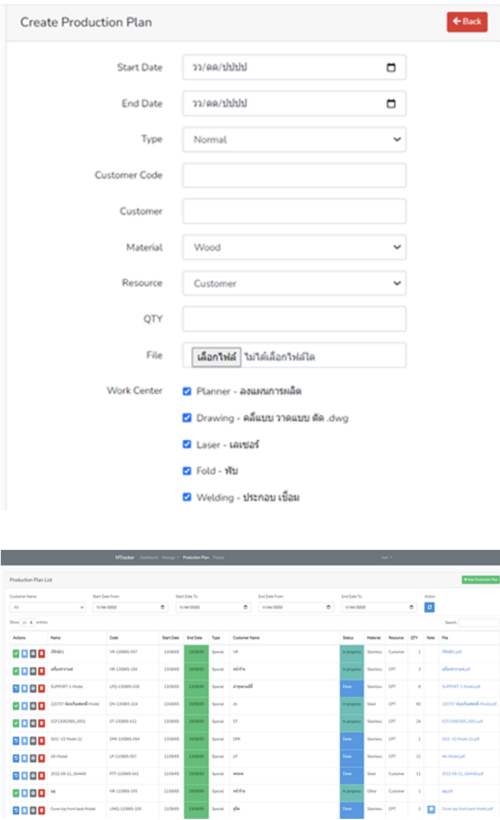


Figure 4. The main activity of the web application system is depicted by the production plan and dashboard function for monitoring real-time capacity.

The resulting conceptual design was represented using a swim-lane diagram, as shown in Fig. 1. The diagram illustrates the relationships among production processes, user roles, information flow, and system functions. This visualization facilitated the identification of

essential features and supported the development of a user-centered system architecture aligned with operational requirements.

4.4 Results of the Prototype Stage

A web-based production management system prototype was developed based on the requirements and conceptual design generated during the previous stages. The user interface was designed to closely align with actual production workflows and operational practices.

The interface design followed the usability principles defined in ISO 9241-11 (International Organization for Standardization, 1998). Simplicity, accessibility, and ease of navigation were prioritized to accommodate users with varying levels of digital literacy. Layout structure, visual elements, and interface components were intentionally designed to emphasize functional clarity rather than visual complexity.

Examples of the developed user interfaces are presented in Fig. 2, Fig. 3, and Fig. 4.

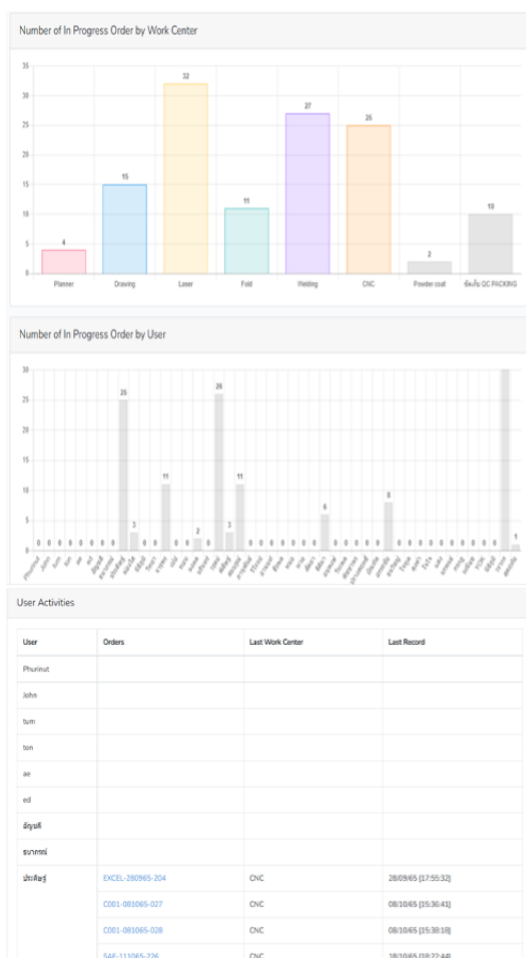


Figure 5. Real-time dashboard for tracking workers and machines.

Number of Order by Customer						
Show	5	g	entries	Search:		
Customer Code	Customer Name	No. of Order	No. of Done	Total QTY	Last End Date	
AGC	AGC	1,686	3,353	103,072	26/11/65	
EXCEL	Excel	1,111	2,214	63,259	15/05/08	
DN	dn	805	1,609	7,426	12/11/65	
T&T	flusaveila	749	1,497	8,025	14/11/65	
LIHQ	gdn	563	1,124	8,389	15/11/65	

Figure 6. Real-time dashboard for tracking order by customer.

The system screens shown in Fig. 5 were specifically designed to address the challenge of evaluating workforce and machine capacity. Planning officers could assign employees to workstations and equipment, while real-time dashboards provided immediate visibility into workforce productivity and machine utilization.

In addition, the interface illustrated in Fig. 6 supported real-time monitoring of production orders for individual customers. This functionality addressed one of the primary concerns identified during the empathize stage, namely the inability to monitor production status efficiently across multiple customer orders.

4.5 Usability Test Results: A Mixed-Methods Analysis

The final prototype was evaluated by all twenty participants to determine whether the developed system satisfied user requirements and usability expectations. A mixed-methods approach combining qualitative and quantitative assessment was employed.

4.5.1 Qualitative Feedback

As summarized in Table 3, participant feedback was highly positive. Users reported that the system was intuitive, easy to use, and considerably simpler than the previous spreadsheet-based process. Several suggestions for future improvement were also identified, including Thai language support and improved display optimization for smaller mobile devices. These recommendations provide valuable directions for future system development.

4.5.2 Quantitative Feedback

To complement the qualitative findings, user satisfaction was assessed using a six-item questionnaire based on a five-point Likert scale. The system achieved a mean satisfaction score of 4.52 with a standard deviation of 0.51, indicating a high level of user acceptance and satisfaction.

The quantitative findings provide strong evidence that the user-centered design approach successfully addressed usability concerns while supporting technology

Table 3. Results of user evaluation criteria.

Question Items	Satisfied	Unsatisfied
Q1. Practical use, easy to use, and quick to understand.	Easy to use and not complex to understand.	No status indication when the system cannot connect to the Internet.
Q2. Appropriate design for the user.	Quick to use and better than the current system (Excel spreadsheet).	Some mobile devices cannot properly display screens. The system should support a wider range of mobile devices.
Q3. Provides precise and reliable results.	The data and results generated by the main functions are acceptable.	Dashboard updates may occasionally be delayed because of Internet connectivity and network speed limitations.
Q4. Compatibility between main functions and the user interface menu.	The main activities can be performed easily and conveniently.	The production planning document cannot currently be printed directly from the system screen.
Q5. Design menus, buttons, colors, and fonts are easy for all users.	The interface design was acceptable to all users.	Some text should be displayed in Thai to improve comprehension and usability.
Q6. Appropriate screen size and visibility.	Production capacity can be monitored and evaluated efficiently.	Data entry on small mobile devices remains difficult for some users.

adoption among users with diverse levels of digital proficiency.

4.6 Analysis of System Efficiency and Cost-Benefit

Operational data collected during the twelve-month period following system implementation were analyzed to evaluate the impact of the proposed system on organizational performance.

4.6.1 Process Time Analysis

The implementation of the production management system resulted in substantial reductions in operational processing times. As illustrated in Fig. 7, production status monitoring time was reduced by 81.1%, while reporting time decreased by 80.7%.



Figure 7. Comparison of operational processing times before and after system implementation.

These improvements indicate that real-time information availability and automated data management significantly enhanced operational efficiency and reduced administrative workload.

4.6.2 Cost-Benefit Analysis

The operational improvements generated measurable financial benefits. As shown in Fig. 8, overtime expenses decreased by 44.4%, while production waste costs were reduced by 46.7%.

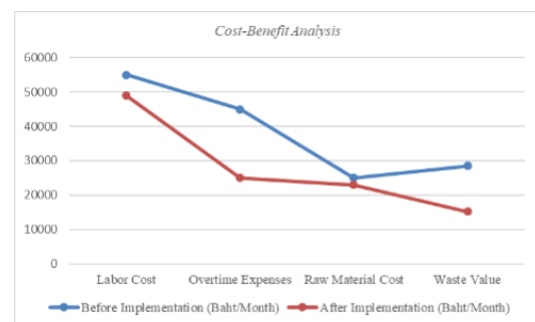


Figure 8. Comparative analysis of key operational costs before and after system implementation.

These findings demonstrate that improvements in information accessibility and production visibility can contribute directly to cost reduction and operational optimization. The results are consistent with previous findings emphasizing the importance of real-time

production information for manufacturing management (Rácz-Szabó *et al.*, 2020).

4.7 Impact of Design Thinking on Technology Adoption

Beyond operational improvements, the study examined the broader organizational impact of the Design Thinking approach.

4.7.1 Conventional Technology-First Scenario

In a conventional technology-first implementation approach, system requirements are typically determined primarily by technical specialists and management personnel, with limited involvement from end-users. Although such systems may satisfy functional requirements, they often experience resistance to adoption due to insufficient consideration of user capabilities, workflows, and practical constraints.

In environments characterized by low digital literacy, these limitations can result in reduced system utilization, user frustration, and failure to achieve intended organizational benefits.

4.7.2 Design Thinking Scenario

In contrast, the Design Thinking approach actively involved users throughout all stages of system development. Employees from multiple organizational levels participated in identifying problems, defining requirements, evaluating prototypes, and providing feedback.

The high user satisfaction score ($Mean = 4.52$) and successful adoption of the system suggest that this participatory process contributed substantially to project success. User involvement facilitated the identification of practical requirements that might otherwise have been overlooked, including interface simplification, workflow alignment, and accessibility considerations.

These findings indicate that Design Thinking can play an important role in reducing digital literacy barriers and improving technology adoption outcomes within SME environments. By prioritizing empathy, collaboration, and iterative refinement, organizations can develop digital solutions that better align with user capabilities and operational needs.

5. Discussion and Conclusion

This study addressed a critical challenge in SME digital transformation: the gap between technological potential and workforce digital literacy. The findings demonstrate that a user-centric Design Thinking approach can facilitate successful technology adoption while generating measurable operational and organizational benefits. This section discusses the validity and implications of the findings, examines their applicability to the broader

SME sector, and outlines limitations and opportunities for future research.

5.1 Evidence-Based Validation of the Design Thinking Framework

The findings provide strong evidence supporting the effectiveness of the proposed Design Thinking framework. The success of the framework is demonstrated through both quantitative and qualitative outcomes. Quantitatively, the system achieved a high user satisfaction score ($Mean = 4.52, SD = 0.51$), an 81.1% reduction in production monitoring time, and a 44.4% reduction in overtime expenses. These improvements indicate that the developed system successfully addressed operational challenges while enhancing organizational efficiency.

Qualitative findings further support these results. Active participation throughout the Design Thinking process encouraged collaboration among managers, supervisors, planning officers, and production workers. This collaborative environment facilitated the identification of practical requirements and operational concerns that may not have been captured using conventional technology-centered development approaches. The resulting alignment between system functionality and user expectations contributed substantially to the high levels of acceptance and adoption observed during implementation.

These findings are consistent with previous studies that emphasize the value of user-centered and empathy-driven approaches in digital transformation initiatives (Vendraminelli *et al.*, 2023). The present study extends this body of knowledge by providing empirical evidence from a manufacturing SME operating within a developing economy and characterized by varying levels of digital literacy.

5.2 Generalizability and Scalability for the SME Sector

Although this study was conducted within a single manufacturing SME, the proposed framework was designed to be transferable to other SME contexts. The core principles of Design Thinking, including empathy, user participation, iterative development, and continuous feedback, are not industry specific and can be applied across a wide range of organizational settings.

The technological implementation also supports scalability. The use of a web-based architecture and open-source development tools reduces implementation costs and increases accessibility for resource-constrained organizations. Consequently, the framework may provide a practical alternative to large-scale enterprise systems that are often financially unattainable for SMEs.

Furthermore, the framework may be particularly beneficial for organizations whose employees possess diverse levels of digital proficiency. By prioritizing accessibility and usability throughout the development pro-

cess, the framework supports inclusive technology adoption and reduces barriers associated with digital literacy limitations.

5.3 Limitations and Future Research Directions

Several limitations should be acknowledged. First, the study was conducted within a single organization, which limits the statistical generalizability of the findings. Future studies should evaluate the framework in different industries, including service, agricultural, and logistics sectors, to assess its broader applicability.

Second, the evaluation period was limited to one year following implementation. Although substantial operational improvements were observed, the long-term sustainability of these outcomes remains uncertain. Longitudinal studies are needed to investigate long-term system usage, organizational adaptation, and return on investment.

Future research may also explore additional technical enhancements identified through user feedback, including improved offline functionality, enhanced mobile support, and integration with emerging digital technologies. These developments could further improve system accessibility and increase the effectiveness of technology adoption initiatives within SME environments.

In conclusion, this study presents a validated Design Thinking framework that addresses digital literacy challenges in SME digital transformation. The framework contributes to the literature by providing empirical evidence from a developing economy, demonstrating the effectiveness of a user-centered approach for technology adoption, and offering a practical methodology that can be replicated by other organizations. The findings further demonstrate that successful digital transformation requires more than technological innovation alone; it requires solutions that align with user capabilities, workplace realities, and organizational needs. Consequently, the proposed framework offers a practical resource for SMEs, system developers, and policymakers seeking to promote inclusive and sustainable digital transformation.

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CRediT Authorship Contribution Statement

Somkeit Noamna: Conceptualization, Methodology, Software, Validation, Investigation, Resources, Data curation, Visualization. **Porntida Kaewkamol:** Funding acquisition, Writing - original draft. **Thanyaphongphat:** Conceptualization, Methodology, Formal analysis, Validation, Investigation, Resources, Writing - review & editing.

Declaration of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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