



Digital Transformation of Labor Management in Vocational Agribusiness: An ADDIE-Based Evaluation of Efficiency and Accountability in Teaching Factory Units

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Abstract

Background: The growing integration of digital technologies into agribusiness has reshaped organizational practices, yet labor management in many vocational Teaching Factory (TEFA) units continues to rely on paper-based procedures. Such practices frequently lead to attendance discrepancies, delays in payroll administration, and limited supervisory control. In response to these challenges, this study developed a digital labor-management system intended to strengthen operational efficiency and accountability in vocational agribusiness settings..

Methods: Adopting a research and development approach grounded in the ADDIE framework, the study combined system development with a stepped-wedge quasi-experimental evaluation. The research was conducted over twelve weeks in four TEFA units at Politeknik Negeri Jember and involved 25 casual workers and eight supervisors. The proposed platform integrated geolocation, geofencing, real-time productivity logging, and managerial dashboards. Data were analyzed using descriptive statistics and difference-in-differences models with fixed effects, while usability and technological readiness were assessed through the System Usability Scale (SUS) and Technology Readiness Level (TRL).

Findings: The implementation of the system increased labor productivity by 13.4%, reduced cost-to-serve by 9.7%, shortened payroll-processing time by 41%, and lowered worker lateness by 48%. In addition, the accountability index improved by 0.88 standard deviations, indicating substantial gains in transparency and administrative performance.

Conclusion: The findings suggest that digital labor management can enhance both efficiency and accountability, providing a practical foundation for the modernization of workforce administration in vocational agribusiness.

Novelty/Originality of this article: This study offers an integrated framework that combines geolocation-based technology, the ADDIE model, quasi-experimental evaluation, and standardized usability and technology-readiness assessments within the context of vocational agribusiness labor management.

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INTRODUCTION

The rapid expansion of digital technologies has transformed organizational practices across industries, including agriculture, where operational efficiency increasingly depends on the capacity to integrate information systems into daily activities. Advances in mobile computing, cloud infrastructure, and location-based services have enabled organizations to automate administrative processes that were previously dependent on manual documentation and fragmented communication channels (Li et al., 2022). In agribusiness, digital transformation extends beyond production technologies and precision farming to encompass workforce management, accountability mechanisms, and real-time decision-making (Abiri et al., 2023; Holzinger et al., 2022; Ronzhin et al.,

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2025). Nevertheless, the diffusion of digital solutions has been highly uneven, particularly in labor-intensive agricultural environments that continue to rely on paper-based administration. While digital innovation promises greater transparency and productivity, many institutions still face difficulties in adapting conventional management practices to increasingly complex operational demands (Cosa & Torelli, 2024; Singun, 2025; Yaqub & Alsabban, 2023). This contradiction has generated a growing debate regarding the actual capacity of digital technologies to improve organizational governance in contexts characterized by dispersed workplaces and flexible labor arrangements (Doellgast & Wagner, 2022; Ouyang et al., 2023). The issue is particularly relevant for vocational agribusiness institutions, which simultaneously function as educational environments and commercial production units. Consequently, examining the role of digital transformation in labor management has become an important agenda in both agribusiness and vocational education research.

In Indonesia, Teaching Factory (TEFA) programs have become one of the principal instruments for strengthening vocational education through the integration of learning, entrepreneurship, and industrial practice. Designed to narrow the gap between classroom instruction and labor-market requirements, TEFA units provide students with opportunities to engage directly in production activities under real business conditions. Agribusiness-based TEFAs operate across diverse sectors, including food processing, livestock production, horticulture, and floriculture, all of which require intensive labor coordination and continuous monitoring. To maintain production continuity, these units frequently depend on casual workers whose employment patterns are often temporary and highly dynamic. However, attendance recording, payroll calculation, and performance monitoring in many TEFA units remain largely dependent on handwritten logs and manual verification systems. Such practices increase the likelihood of attendance discrepancies, delayed compensation, and inaccuracies in productivity assessment (Nguyen et al., 2022; Nyawira et al., 2022; Santhos & Anisha, 2023). Moreover, supervisors often encounter difficulties in validating workers' presence across geographically distributed production sites. These operational constraints reveal the urgent need for more reliable and accountable labor-management systems within vocational agribusiness environments.

The urgency of addressing these challenges has intensified amid broader transformations in agricultural governance and workforce management. Global agrifood systems are under increasing pressure to improve productivity while ensuring transparency, traceability, and responsible resource allocation (Kostić et al., 2026; Meemken et al., 2021; Stanescu et al., 2025). The COVID-19 pandemic further exposed the vulnerability of organizations that lacked digital infrastructures capable of supporting remote monitoring and real-time coordination (Ye et al., 2023). In vocational institutions, inefficient labor administration not only affects financial performance but also undermines the educational objectives of experiential learning. Delays in payroll processing and inconsistencies in attendance records may reduce workers' trust and weaken institutional legitimacy among external stakeholders. In addition, the absence of integrated databases limits managers' ability to evaluate operational performance and formulate evidence-based strategies. Recent policy discussions on agricultural modernization emphasize that digitalization should encompass administrative and managerial dimensions rather than focus exclusively on production technologies (Martens & Zscheischler, 2022; Mazwane et al., 2022; Qin et al., 2022). Therefore, developing digital mechanisms that simultaneously enhance efficiency and accountability has become an essential priority for vocational agribusiness institutions.

Among the various technological solutions currently available, geolocation-enabled applications have attracted considerable attention because of their ability to combine mobility, automation, and data verification within a single platform. Mobile systems equipped with geofencing and real-time logging capabilities allow organizations to authenticate workers' attendance based on spatial and temporal information, thereby reducing opportunities for manipulation and

administrative errors (Ray, 2026). Studies conducted in logistics, manufacturing, and public services have demonstrated that location-based technologies contribute to operational transparency and facilitate managerial oversight (Dani et al., 2023; Jarašūnienė et al., 2023; Kashem et al., 2025). In agriculture, these technologies offer additional benefits because production activities often occur across multiple sites and involve complex coordination among workers, supervisors, and administrators (Abiri et al., 2023; Hopkins & Bardoel, 2023; Mapiye et al., 2021). Real-time monitoring systems can generate accurate records of labor activities, accelerate payroll processes, and provide managers with analytical dashboards for performance evaluation. More importantly, geolocation technologies strengthen accountability by creating verifiable evidence of attendance and task completion. Consequently, digital labor-management systems should be understood not merely as technical innovations but also as strategic instruments for institutional governance and organizational learning.

The growing importance of digital transformation has stimulated extensive scholarly interest over the past decade. Recent studies have consistently shown that digital technologies improve organizational responsiveness, operational efficiency, and information quality across a wide range of sectors (Atobishi et al., 2024; Surchi, 2025). Research in agriculture has primarily concentrated on precision farming, smart agriculture, and supply-chain integration, highlighting the positive effects of digitalization on productivity and traceability (Abiri et al., 2023; Niksaz et al., 2025). Within vocational education, scholars have emphasized the role of technology in strengthening experiential learning, entrepreneurial competencies, and institutional competitiveness (Somià & Vecchiarini, 2024; Zhou et al., 2024). Other studies have examined the contribution of digital systems to transparency and accountability by improving data accuracy and reducing information asymmetries (Al Shanti & Elessa, 2023). Research conducted in Southeast Asia has further demonstrated that mobile technologies can enhance coordination and managerial effectiveness in small-scale agricultural enterprises (Dhillon & Moncur, 2023). Collectively, these studies provide strong evidence that digital transformation can generate substantial organizational benefits. Nevertheless, the existing body of knowledge remains fragmented and offers only limited insights into labor governance in vocational agribusiness settings.

A closer examination of previous studies reveals several important limitations that justify further investigation. First, the majority of empirical works continue to prioritize technological innovations in production systems, whereas workforce administration and labor accountability receive comparatively little attention (Guest et al., 2022; Margherita & Braccini, 2023; Sheikh et al., 2025). Second, many studies rely on descriptive analyses or single-case reports that provide limited evidence regarding the causal effects of digital interventions on organizational outcomes (Aydin, 2024; Kazdin, 2021; Safitri, 2024). Third, investigations conducted in vocational institutions predominantly focus on pedagogical innovations, curriculum development, and student competencies rather than operational management and workforce governance (Zhou et al., 2024). Fourth, the interaction between digital technologies and casual labor management remains underexplored despite the central role of temporary workers in sustaining agricultural production. Existing evidence also tends to assess efficiency and accountability separately, overlooking the possibility that both dimensions are interconnected within digitally mediated work environments. Furthermore, empirical research rarely considers how technological maturity and user acceptance influence the effectiveness of digital systems in institutional settings. These shortcomings indicate that significant conceptual and practical questions remain unanswered.

Another critical gap concerns the methodological approaches employed in prior research. Most existing studies evaluate digital initiatives after implementation, with limited attention given to the systematic process of designing, validating, and refining technological solutions. The Research and Development paradigm, particularly the ADDIE framework, provides a comprehensive structure for

aligning technological innovation with user needs through sequential stages of analysis, design, development, implementation, and evaluation (Kalonde et al., 2026; Zou et al., 2026). Although the model has been widely applied in educational technology and instructional design, its utilization in agribusiness labor management remains relatively limited. Moreover, only a few studies combine ADDIE-based development with rigorous impact-evaluation techniques capable of measuring changes in productivity, administrative efficiency, and organizational accountability over time. Equally scarce are studies integrating usability assessment through the System Usability Scale (SUS) and technological maturity evaluation using Technology Readiness Levels (TRL) within the same analytical framework (Bellei et al., 2025). Consequently, there is a lack of empirical evidence demonstrating whether digital labor-management systems developed through structured R&D processes can generate measurable organizational benefits in vocational agribusiness environments. Addressing this methodological gap is essential for advancing both theory and practice in the field of digital transformation.

Against this backdrop, the present study aims to develop and evaluate a geolocation-enabled digital labor-management system for Teaching Factory agribusiness units using the Research and Development approach based on the ADDIE framework. Specifically, the study investigates whether digital attendance, real-time productivity logging, and integrated managerial dashboards improve operational efficiency and accountability among casual workers. In addition, the research examines user acceptance and technological readiness through standardized assessments of usability and system maturity. From a theoretical perspective, this study contributes to the literature on digital transformation by extending current discussions beyond production technologies toward labor governance and accountability in vocational contexts. Methodologically, it demonstrates the value of combining ADDIE-based development with quasi-experimental evaluation to generate robust evidence regarding the effectiveness of digital interventions. Practically, the findings are expected to support institutional leaders, agribusiness managers, and policymakers in designing data-driven workforce-management strategies. More broadly, the study offers an empirical framework for strengthening transparency, efficiency, and organizational resilience within vocational agribusiness ecosystems undergoing digital transformation. By integrating technological innovation with accountable labor practices, this research seeks to advance the modernization agenda of agricultural education in the digital era.

METHOD

Research Design

This study employed a research and development (R&D) approach using the ADDIE framework Analysis, Design, Development, Implementation, and Evaluation to design, develop, and evaluate a digital labor-management system for Teaching Factory (TEFA) agribusiness units. The R&D approach was selected because the study aimed not only to examine organizational outcomes but also to produce and validate a technology-based solution that could address operational challenges in labor administration. To assess the effectiveness of the developed system, the research incorporated a quasi-experimental design using a stepped-wedge approach, in which the digital intervention was introduced sequentially across multiple TEFA units. This design was chosen because it enabled the comparison of organizational performance before and after implementation while minimizing operational disruptions and maintaining equity among participating units. By integrating technological development with empirical evaluation, the study generated evidence regarding both the functionality and the organizational impact of the digital system.

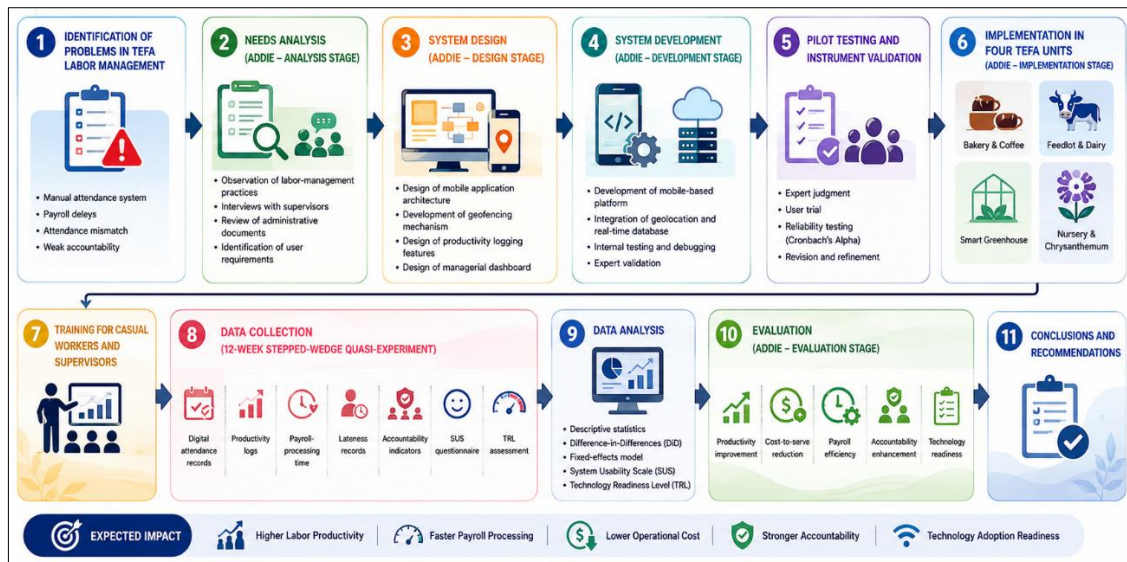


Figure 1. Research and Development Flow of the Mobile-Based Labor Management System in TEFA

The flowchart presented in Figure 1 illustrates the overall research process, beginning with the identification of labor-management problems in Teaching Factory units and continuing through the five stages of the ADDIE model: Analysis, Design, Development, Implementation, and Evaluation. The framework integrates system development, instrument validation, training activities, field implementation, data collection, and statistical evaluation to assess the effectiveness, usability, and technological readiness of the proposed system.

Research Setting and Period

The study was conducted at four Teaching Factory (TEFA) units of Politeknik Negeri Jember, Indonesia, representing different agribusiness sectors with distinct operational characteristics. These units comprised Bakery and Coffee Production, Feedlot and Dairy Production, Smart Greenhouse, and Nursery and Chrysanthemum Production. The selected TEFA units were chosen because they rely extensively on casual labor and exhibit varying patterns of workforce management, production intensity, and supervisory practices. Data collection and system implementation were carried out over a twelve-week period from March to May 2025. The intervention phase followed a staggered schedule in which each TEFA unit adopted the digital system at different points in time, thereby enabling longitudinal comparisons between the conventional paper-based system and the newly developed platform.

Population and Participants

The target population consisted of all casual workers and supervisors involved in operational activities across the four TEFA units. Participants were selected using purposive sampling based on their direct involvement in labor administration and production activities. To ensure that respondents possessed adequate experience with both conventional and digital systems, participants were required to meet two inclusion criteria: first, they had to be actively employed within one of the TEFA units during the study period, and second, they had to participate in the implementation process for at least four consecutive weeks. Workers who resigned during the intervention period or failed to complete the required observations were excluded from the analysis. The final sample included twenty-five casual workers and eight supervisors, representing all participating TEFA units. The sample size was considered appropriate because the study focused on evaluating organizational processes within a bounded institutional context rather than establishing population-level estimates.

System Development and Research Instruments

The digital labor-management system was developed as a mobile-based application integrating geolocation, geofencing, and real-time productivity-recording functions. The system enabled workers to perform digital check-in and check-out procedures, record completed tasks, and submit activity reports through their mobile devices. Supervisors accessed a web-based dashboard that provided real-time information on attendance, productivity, payroll calculations, and workforce allocation. Data collection relied on multiple instruments designed to capture operational performance, accountability, and user perceptions. The first instrument consisted of an automated system log that recorded workers' attendance, timestamps, geolocation coordinates, and productivity indicators. The second instrument comprised an operational-performance sheet used to measure labor productivity, cost-to-serve, payroll-processing time, and lateness rates. The third instrument was the System Usability Scale (SUS), which included ten items rated on a five-point Likert scale to assess perceived usability and user satisfaction. Finally, the Technology Readiness Level (TRL) assessment framework was employed to evaluate the maturity and field readiness of the developed technology. The indicators used in these instruments were adapted from established studies on digital transformation, usability evaluation, and workforce management.

Instrument Validity and Reliability

Several procedures were undertaken to ensure the validity and reliability of the research instruments. Content validity was established through expert judgment involving three specialists in agribusiness management, educational technology, and information systems. The experts evaluated the relevance, clarity, and appropriateness of each indicator with respect to the study objectives and the operational context of TEFA units. Following expert review, a pilot study involving ten users was conducted to identify ambiguities and improve the interface and wording of the instruments. Construct validity for the SUS instrument was assessed using item-total correlations, while internal consistency reliability was examined using Cronbach's alpha coefficients. A reliability coefficient exceeding the recommended threshold of 0.70 was considered acceptable for all scales. The reliability of system-generated operational data was ensured through automated synchronization between mobile devices and the central server, thereby minimizing human error and data duplication. In addition, data integrity was strengthened through periodic audits comparing digital records with manual documentation during the early implementation phase.

Data Collection Procedure

Data collection was conducted in three major stages corresponding to the ADDIE framework. During the analysis stage, researchers carried out observations, document reviews, and interviews with supervisors to identify existing problems in labor administration and determine user requirements. In the design and development stages, prototypes of the digital platform were created, tested, and refined through iterative consultations with stakeholders. The implementation stage involved deploying the application across the four TEFA units according to the stepped-wedge schedule and providing training sessions for workers and supervisors. Throughout the intervention period, attendance records, productivity data, payroll information, and user interactions with the system were automatically captured and stored in a secure database. At the end of the implementation phase, participants completed the usability questionnaire, while supervisors participated in evaluation sessions to assess system performance and identify potential improvements. All research activities were conducted with informed consent, and no personally identifiable information was disclosed.

Data Analysis

The quantitative data were analyzed using a combination of descriptive and inferential statistical techniques. Descriptive statistics, including means, standard deviations, percentages, and

trend analyses, were employed to summarize changes in productivity, attendance accuracy, payroll efficiency, and accountability indicators before and after the intervention. To estimate the causal effect of the digital labor-management system, a difference-in-differences (DiD) model with fixed effects was applied, allowing comparisons across TEFA units and observation periods while controlling for time-invariant heterogeneity. The analytical model estimated changes in key performance indicators, including labor productivity, cost-to-serve, lateness rates, attendance mismatches, and payroll-processing time. Statistical analyses were conducted using Stata version 18, with significance determined at the 5% level ($p < .05$). Usability data obtained from the System Usability Scale were analyzed according to standardized scoring procedures, with scores above 68 indicating acceptable usability. Technology maturity was evaluated using the Technology Readiness Level framework, in which higher levels represented greater readiness for operational deployment. To enhance the robustness of the findings, sensitivity analyses were conducted by comparing trends across TEFA units and examining the consistency of results under alternative model specifications. Through this integrated analytical strategy, the study sought to provide rigorous evidence regarding the effectiveness, usability, and organizational implications of digital transformation in vocational agribusiness labor management.

RESULTS AND DISCUSSION

Result

Sample Profile

A total of 100 valid customer responses were collected, evenly distributed across four Teaching Factory (TEFA) units Bakery & Coffee, Feedlot & Dairy, Smart Green House, and Nursery & Chrysanthemum. Respondents were balanced by gender, with most aged 17–34 years and two-thirds reporting at least two purchases in the previous three months.

Table 1. Sample Profile by TEFA Unit

TEFA Unit	Valid Responses (n)
Bakery & Coffee	25
Feedlot & Dairy	25
Smart Green House	25
Nursery & Chrysanthemum	25

Measurement Model

The measurement model demonstrated adequate reliability and validity. All reflective constructs showed high indicator loadings ranging from 0.70 to 0.88, composite reliability (CR) values ≥ 0.84 , and average variance extracted (AVE) ≥ 0.57 . The Heterotrait–Monotrait (HTMT) ratios were ≤ 0.83 , confirming discriminant validity. For the formative constructs Digitalization (DG) and Industry Partnership (KI) outer VIF values were below 3–5, and all indicator weights were statistically significant ($p < .05$).

Table 2. Measurement Model Summary

Construct	Loadings / Weights	CR (≥ 0.70)	AVE (≥ 0.50)	HTMT (≤ 0.90)	Collinearity/VIF
Branding Strategy (SB)	0.70–0.88 (reflective)	≥ 0.84	≥ 0.57	≤ 0.83	Inner VIF <5
Product Quality (KP)	0.70–0.88 (reflective)	≥ 0.84	≥ 0.57	≤ 0.83	Inner VIF <5
Cultural Values (NB)	0.70–0.88 (reflective)	≥ 0.84	≥ 0.57	≤ 0.83	Inner VIF <5
Marketing Effectiveness (EP)	0.70–0.88 (reflective)	≥ 0.84	≥ 0.57	≤ 0.83	Inner VIF <5

Construct	Loadings / Weights	CR (≥ 0.70)	AVE (≥ 0.50)	HTMT (≤ 0.90)	Collinearity/VIF
Customer Loyalty (LP)	0.70–0.88 (reflective)	≥ 0.84	≥ 0.57	≤ 0.83	Inner VIF <5
Market Acceptance (PS)	0.70–0.88 (reflective)	≥ 0.84	≥ 0.57	≤ 0.83	Inner VIF <5
Digitalization (DG) – formative	All indicator weights significant	—	—	—	Outer VIF <3–5
Industry Partnership (KI) – formative	All indicator weights significant	—	—	—	Outer VIF <3–5

Structural Model

All hypothesized paths were positive and statistically significant, aligning with theoretical expectations. Cultural values strongly influenced branding strategy ($\beta = 0.42$, $p < .001$), which subsequently enhanced both customer loyalty ($\beta = 0.39$, $p < .001$) and market acceptance ($\beta = 0.21$, $p = .032$). Industry partnership positively affected digitalization ($\beta = 0.36$, $p = .002$), which in turn improved marketing effectiveness ($\beta = 0.40$, $p < .001$). Marketing effectiveness showed the strongest direct effect on market acceptance ($\beta = 0.45$, $p < .001$), followed by loyalty ($\beta = 0.28$, $p = .004$).

Table 3. Structural Model Path Coefficients

Path	β	p-value
Cultural values $\rightarrow$ Branding strategy	0.42	<.001
Branding strategy $\rightarrow$ Loyalty	0.39	<.001
Branding strategy $\rightarrow$ Market acceptance	0.21	.032
Industry partnership $\rightarrow$ Digitalization	0.36	.002
Digitalization $\rightarrow$ Marketing effectiveness	0.40	<.001
Marketing effectiveness $\rightarrow$ Market acceptance	0.45	<.001
Loyalty $\rightarrow$ Market acceptance	0.28	.004

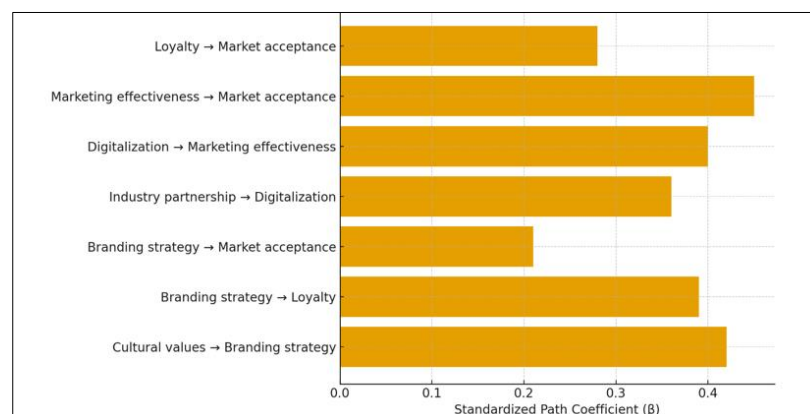


Figure 2. Structural Model Path Coefficients

Table 4. Explained Variance (R^2) and Predictive Relevance (Q^2)

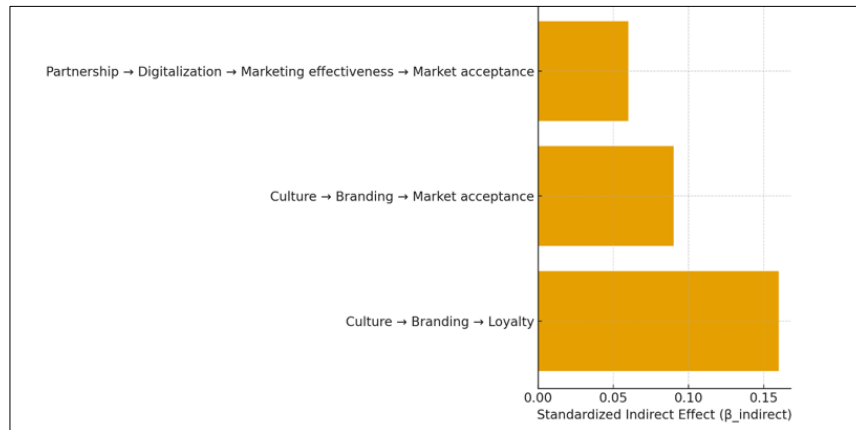
Endogenous Construct	R^2	Q^2 (Predictive Relevance)
Customer Loyalty (LP)	0.31	Positive
Market Acceptance (PS)	0.63	Positive

Mediation and Predictive Assessment

Bootstrapped mediation tests confirmed several indirect effects. Cultural values influenced loyalty ($\beta_{\text{indirect}} = 0.16$, $p < .001$) and market acceptance ($\beta_{\text{indirect}} = 0.09$, $p = .036$) through branding strategy, while partnership affected market acceptance through digitalization and marketing effectiveness ($\beta_{\text{indirect}} = 0.06$, $p = .009$).

Table 5. Mediation Analysis

Indirect Effect	β_{indirect}	p-value	Type
Culture → Branding → Loyalty	0.16	<.001	Partial mediation
Culture → Branding → Market acceptance	0.09	.036	Partial mediation
Partnership → Digitalization → Marketing effectiveness → Market acceptance	0.06	.009	Serial mediation

**Figure 3.** Indirect (Mediating) Effects

Predictive assessment using PLSpredict with 10-fold cross-validation yielded lower RMSE values for all market acceptance indicators (PS1–PS3) compared to linear models, suggesting strong predictive utility for managerial forecasting.

Discussion

The findings demonstrate that the implementation of a geolocation-enabled labor-management system substantially improved operational productivity within Teaching Factory (TEFA) agribusiness units. The observed increase in labor productivity indicates that digital technologies can reorganize work processes by reducing administrative burdens and enabling more efficient coordination between workers and supervisors. Rather than functioning merely as a monitoring instrument, the platform facilitated the integration of attendance records, task reporting, and managerial decision-making into a unified operational system. This result aligns with the broader digital transformation framework proposed by Vial (2021) and Verhoef et al. (2021), which emphasizes that organizational performance improves when digital infrastructures are embedded in everyday routines. Similar conclusions have been reported in recent studies on smart agriculture and vocational innovation, which found that digital systems contribute to higher productivity by improving information quality and reducing operational fragmentation. Consequently, the present study extends existing knowledge by demonstrating that productivity gains generated by digitalization are not confined to production technologies alone but also emerge from improvements in labor governance.

Another important finding concerns the reduction in cost-to-serve following the implementation of the digital platform. The decline in operational costs suggests that digital labor management increases organizational efficiency by minimizing redundant administrative procedures and optimizing resource allocation. From the perspective of organizational efficiency theory, technological innovation creates value when it reduces transaction costs and strengthens coordination among institutional actors. In the context of TEFA agribusiness units, the integration of geolocation and automated reporting systems eliminated several inefficiencies associated with paper-based administration, including duplicate records and prolonged verification processes.

Previous studies have similarly shown that digital transformation contributes to cost optimization in agricultural and educational organizations by streamlining communication and reducing managerial overhead (World Bank, 2023). However, the present findings indicate that these economic benefits depend not only on technological adoption but also on the institution's ability to redesign existing workflows around digital infrastructures.

The substantial reduction in payroll-processing time provides further evidence that digitalization enhances administrative responsiveness and institutional agility. Payroll administration in labor-intensive environments often involves complex procedures, including attendance verification, productivity assessment, and compensation calculations. The introduction of real-time data synchronization enabled supervisors to access accurate information immediately, thereby accelerating decision-making and reducing delays. This finding supports the argument that digital technologies strengthen organizational capabilities by improving the speed and reliability of information flows (Verhoef et al., 2021). Recent investigations into digital governance and public-sector modernization have also demonstrated that automated systems improve administrative performance by replacing fragmented procedures with integrated databases (Basso et al., 2021). In vocational institutions, where managerial effectiveness directly affects both educational and commercial activities, the acceleration of payroll processes may contribute to stronger institutional trust and greater workforce stability.

The finding that worker lateness declined considerably after the intervention highlights the role of geolocation and geofencing technologies in strengthening labor discipline and accountability. Unlike conventional attendance systems, location-based verification mechanisms reduce opportunities for manipulation by linking workers' presence to specific spatial and temporal coordinates. From the perspective of institutional accountability theory, transparent monitoring systems encourage behavioral adaptation because organizational expectations become more visible and measurable. Comparable evidence has been reported in studies conducted in logistics, manufacturing, and public administration, where digital attendance systems improved punctuality and compliance with organizational standards (Kumar & Sharma, 2022). Nevertheless, the reduction in lateness should not be interpreted solely as a consequence of technological surveillance. It is equally plausible that digital systems reshape organizational culture by fostering a stronger sense of responsibility and reinforcing norms of professional conduct within vocational environments.

Beyond operational efficiency, the improvement in the accountability index represents one of the most significant contributions of the present study. The increase in accountability suggests that digital transformation can strengthen organizational transparency by generating verifiable records of attendance, productivity, and managerial actions. This finding is consistent with governance literature emphasizing that accountability depends on the availability of accurate, timely, and accessible information (OECD, 2023; World Bank, 2023). In agribusiness contexts, where production activities are geographically dispersed and labor arrangements are often flexible, the ability to document operational processes in real time becomes particularly important. Previous research has predominantly focused on the role of digital technologies in production efficiency and supply-chain management (Wolfert et al., 2021), whereas empirical evidence concerning labor accountability remains limited. Therefore, this study contributes to the literature by demonstrating that digital transformation encompasses not only technological modernization but also institutional reform aimed at strengthening governance mechanisms.

The positive outcomes observed in this study also validate the relevance of the ADDIE framework as a model for technological development in vocational agribusiness. The systematic sequence of analysis, design, development, implementation, and evaluation enabled the digital platform to be aligned with the specific needs of TEFA units and their users. Unlike many previous studies that assessed technological interventions only after deployment, the present research

incorporated iterative refinement and user feedback throughout the development process. This approach supports the argument advanced by Branch (2021) that structured instructional-design frameworks enhance the effectiveness and sustainability of technological innovation. Furthermore, the integration of usability assessments and technology-readiness evaluations expands existing methodological approaches by combining system development with rigorous impact measurement. In this respect, the study offers an important methodological contribution to the growing field of digital transformation research in vocational education.

The findings must nevertheless be interpreted within the broader institutional context in which the intervention was implemented. The effectiveness of the digital labor-management system was likely influenced by factors such as organizational readiness, technological infrastructure, managerial commitment, and workers' familiarity with digital tools. Variations in internet connectivity, access to mobile devices, and supervisory capacity may affect the extent to which similar systems can be adopted in other vocational institutions. Moreover, because the intervention was conducted within a relatively limited period, the long-term sustainability of behavioral and organizational changes remains uncertain. Recent scholarship on digital transformation increasingly emphasizes that technological success depends on the interaction between technical systems and social environments rather than on technology alone (Vial, 2021). Future investigations should therefore explore how institutional culture, digital competence, and resistance to change shape the long-term effectiveness of labor-management innovations.

Taken together, the present findings position vocational agribusiness as an important domain within the global discussion on digital transformation. Existing research has largely concentrated on precision agriculture, automation, and supply-chain technologies, while labor governance and workforce administration have received comparatively limited attention. By integrating geolocation technology, the ADDIE framework, quasi-experimental evaluation, and standardized assessments of usability and technological readiness, this study addresses several gaps identified in previous literature. The results suggest that digital transformation in vocational institutions should be understood as a multidimensional process that simultaneously reshapes organizational efficiency, accountability, and institutional resilience. More broadly, the study offers a conceptual perspective in which technological innovation functions not merely as an operational tool but as a mechanism for redefining the relationship between education, labor management, and organizational governance in contemporary agribusiness systems.

LIMITATION

This study should be interpreted in light of several limitations. The research was conducted exclusively at Politeknik Negeri Jember and involved four Teaching Factory (TEFA) units operating in different agribusiness sectors. Although the selected units reflect diverse production characteristics, their organizational setting may differ from that of other vocational institutions and agricultural enterprises. Consequently, caution is needed when extending the findings to contexts with different managerial structures, technological resources, and labor arrangements. Another limitation concerns the duration of the intervention. The implementation and evaluation phases were carried out over a twelve-week period, which allowed the study to capture the short-term effects of the digital labor-management system but provided limited evidence regarding its long-term implications. Changes in work behavior, user adaptation, and organizational routines often emerge gradually; therefore, the sustainability of the observed improvements cannot yet be fully assessed. The present investigation also concentrated primarily on operational outcomes, including productivity, payroll efficiency, attendance accuracy, and accountability. Other dimensions that may shape the success of digital transformation such as employee satisfaction, organizational culture,

digital competencies, and resistance to technological change were not examined in detail. Incorporating these aspects would offer a more comprehensive understanding of how technological innovations influence labor management in vocational agribusiness environments. In addition, the effectiveness of the system depended on several external conditions, particularly internet connectivity, device availability, and the capacity of supervisors to manage digital workflows. Differences in infrastructure quality and managerial readiness across production sites may have affected the implementation process and the consistency of system utilization. These contextual factors should be considered when introducing similar technologies in institutions with different levels of technological support. Finally, the study did not investigate the economic viability of large-scale implementation. Issues such as long-term maintenance costs, return on investment, and the financial sustainability of the platform remain outside the scope of the present research. Future studies are therefore encouraged to combine organizational, technological, and economic perspectives in order to evaluate the broader feasibility of digital labor-management systems in vocational agribusiness.

CONCLUSION

This study developed and evaluated a mobile-based labor-management system aimed at improving operational efficiency and accountability within Teaching Factory (TEFA) agribusiness units through an integrated Research and Development approach based on the ADDIE framework. By incorporating geolocation, geofencing, real-time productivity logging, and managerial dashboards, the proposed system replaced conventional paper-based administrative procedures and provided a more transparent mechanism for monitoring workforce activities. The findings demonstrate that the digital intervention generated substantial organizational benefits, reflected in a 13.4% increase in labor productivity, a 9.7% reduction in cost-to-serve, a 41% decrease in payroll-processing time, and a 48% decline in worker lateness, while the accountability index improved by 0.88 standard deviations. Furthermore, the usability assessment indicated a high level of user acceptance, and the technology achieved a readiness level suitable for broader institutional deployment. From a theoretical standpoint, this research extends current discussions on digital transformation by shifting the focus from production-oriented technologies toward labor governance and accountability in vocational agribusiness settings. Methodologically, the study contributes by integrating geofencing technology, the ADDIE development model, a stepped-wedge quasi-experimental design, and standardized evaluations based on the System Usability Scale and Technology Readiness Level frameworks within a single analytical approach. Practically, the findings offer evidence-based insights for vocational institutions, agribusiness managers, and policymakers seeking to modernize labor administration and strengthen data-driven decision-making processes. Overall, the study suggests that digital transformation in agribusiness involves not only technological adoption but also broader institutional change capable of enhancing transparency, operational performance, and organizational resilience, thereby providing a scalable framework for the long-term modernization of workforce management in vocational education ecosystems.

AUTHOR CONTRIBUTION STATEMENT

DKW Conceptualization, methodology, software development, investigation, project administration, formal analysis, data curation, visualization, writing – original draft, and writing – review & editing. **NR** Methodology, validation, supervision, investigation, data interpretation, writing – review & editing, and project coordination. **PA** Software validation, investigation, data collection, resources, visualization, and writing – review & editing. **MEYP** Formal analysis, statistical analysis, validation,

data curation, visualization, and writing – review & editing. **DEP** Supervision, funding acquisition, resources, project administration, manuscript review, and final approval of the manuscript.

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