The Impact of AR/VR Training on Employee Well-Being in the Manufacturing Sector

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Abstract—**The adoption of Augmented Reality (AR) and Virtual Reality (VR) in training has accelerated under Industry 4.0, offering immersive and risk-free environments that enhance learning and performance. While prior studies have demonstrated the technical effectiveness of these tools, less is known about their impact on employee well-being. This study investigates how AR/VR training influences job satisfaction, engagement, and mental health among manufacturing employees. A mixed-methods approach was adopted, combining survey data from 500 employees with in-depth interviews of managers and trainees. Structural Equation Modeling (SEM) was employed to test relationships among training frequency, perceived effectiveness, organizational support, and well-being outcomes. Results confirm that AR/VR training significantly improves employee well-being, with training effectiveness mediating this relationship and organizational support serving as a key moderator. Qualitative findings further reveal that immersive training environments reduce stress and build confidence by providing interactive, supportive learning experiences. This research contributes theoretically by integrating the Technology Acceptance Model (TAM), the Job Demands–Resources (JD-R) model, and Self-Determination Theory (SDT) to explain how immersive training extends beyond performance outcomes to employee welfare. Practically, the study provides managers with strategies to design effective AR/VR training programs that enhance both skills and psychological resilience. The findings highlight AR/VR training as a human-centered approach to digital transformation in manufacturing, advancing both productivity and sustainable workforce well-being.**

Index Terms—**AR/VR training, employee well-being, Industry 4.0, Technology Acceptance Model, Job Demands–Resources, Self-Determination Theory**

I. INTRODUCTION

The rapid advancement of Industry 4.0 has led to significant technological disruptions in the workplace, particularly through the adoption of Augmented Reality (AR) and Virtual Reality (VR) in employee training. These immersive technologies enable experiential learning in controlled environments, reducing risks and enhancing skill acquisition. While prior research has explored their effectiveness in improving performance and safety (Gavish et al., 2013; Moro et al., 2017), the implications for employee well-being remain underexplored, particularly in manufacturing contexts. Recent systematic reviews indicate that immersive training is increasingly positioned as a tool not only for efficiency but also for psychological and organizational outcomes (Carvalho, Conceição, & Marques, 2025; Scorgie et al., 2024).

In the manufacturing sector, employees often face high physical demands, repetitive tasks, and stressful work conditions. Against this backdrop, immersive training can serve as a job resource that reduces stress, increases engagement, and supports mental health. Research has begun to highlight the emotional benefits of immersive experiences, such as improved motivation, reduced anxiety, and stronger workplace confidence (Adhyaru & Kemp, 2022; Kuo et al., 2025). However, most of these insights come from healthcare, retail, or educational settings, with limited evidence in industrial environments.

This study addresses these gaps by examining the impact of AR/VR training on employee well-being in the manufacturing sector, focusing on job satisfaction, engagement, and mental health. By integrating the Technology Acceptance Model (TAM), the Job Demands–Resources (JD-R) model, and Self-Determination Theory (SDT), the research develops an integrated framework to explain how immersive training translates into psychological benefits. Using a mixed-methods approach, the study combines

quantitative analysis with qualitative insights, offering both theoretical contributions and practical implications for Industry 4.0-driven organizations.

As organizations worldwide grapple with rising stress, burnout, and digital adoption challenges, immersive AR/VR training offers a scalable, human-centered approach to workforce well-being, making this study globally relevant beyond the Indian manufacturing context

II. LITERATURE REVIEW

Research on immersive technologies in training has largely emphasized improvements in skill acquisition, safety, and performance. Early studies demonstrated the utility of VR and AR in industrial and medical training contexts, highlighting their role in enhancing accuracy and reducing errors (Seymour et al., 2002; Gavish et al., 2013; Moro et al., 2017). These findings established AR/VR as effective tools for experiential learning, especially in high-risk environments where real-world practice may be costly or dangerous.

AR/VR Training and Safety

Much of the existing literature has focused on safety training. For instance, Webel et al. (2012) developed AR-based platforms that improved assembly and maintenance skills. Similarly, Chalhoub and Ayer (2017) demonstrated that immersive methods enhance design communication in construction projects. More recent reviews reinforce these findings: Scorgie et al. (2024) provide evidence that VR-based safety training significantly improves hazard recognition and emergency response, while Al-Hamad, Wedyan, and Gilányi (2025) highlight the importance of simulation realism and critical thinking in VR safety auditing. Complementing these insights, Zhou and Lee (2024) examined the role of VR in promoting psychological safety in industrial workplaces, showing that immersive training can create safer learning environments for high-risk tasks.

AR/VR and Well-being

While technical benefits are well documented, research exploring psychological and emotional outcomes of AR/VR training remains limited. Riches et al. (2023) found that immersive technologies can enhance mental health and engagement by reducing stress. Adhyaru and Kemp (2022) reported that VR promotes confidence and motivation by creating psychologically safe learning environments. Extending these insights, Kuo et al. (2025) demonstrated how VR meditation reduces workplace stress, while a 2025 study on AR services confirmed positive effects on user satisfaction and psychological engagement (Impact of Augmented Reality Service, 2025). Building on this evidence, Singh and Sharma (2023) showed that digital transformation initiatives in Indian manufacturing improve engagement and well-being, suggesting that immersive training should be considered a key enabler of human-centered Industry 4.0.

Training Effectiveness and Organizational Context

Training outcomes are shaped by both individual perceptions and organizational conditions. Training quality, frequency, and trust significantly influence effectiveness (Diego-Mas, Alcaide-Marzal, & Poveda-Bautista, 2020). Organizational support—through leadership, resources, and cultural readiness—is critical for adoption (Schein & Rauschnabel, 2021). Recent frameworks extend this view: Pireddu, Giliberti, Innocenti, and Simeoni (2025) propose a macro-level VR training evaluation model, while Li and Wang (2023) apply a TAM-UTAUT perspective to explain AR/VR adoption in manufacturing. Their findings emphasize the roles of perceived usefulness, ease of use, and technological literacy in shaping training outcomes. In addition, de Lucas Ancillo, Gavilan, and Rojas (2023) argue that digital skills mediate the relationship between Industry 4.0 adoption and employee well-being, underscoring the broader interplay between technological and human resources.

Synthesis

Overall, the literature highlights that while AR/VR training enhances safety and learning outcomes, its role in employee well-being remains underexplored, especially in manufacturing contexts. Few studies have systematically examined how immersive training influences job satisfaction, engagement, and mental health while accounting for mediators such as training effectiveness and moderators such as organizational support. Addressing this gap, the present study contributes by integrating technology adoption models with well-being theories to provide a holistic understanding of AR/VR training's impact on

workforce sustainability.

Theoretical Framework

This study integrates three theoretical perspectives to explain how AR/VR training influences employee well-being: the Technology Acceptance Model (TAM), the Job Demands–Resources (JD-R) model, and Self-Determination Theory (SDT).

According to TAM, employees' perceptions of usefulness and ease of use shape their acceptance and engagement with new technologies (Schein & Rauschnabel, 2021). In the context of AR/VR training, positive perceptions of these factors are expected to enhance participation and, in turn, well-being outcomes. The JD-R model (Bakker & Demerouti, 2017) suggests that workplace resources can mitigate job demands and foster engagement. AR/VR training may serve as such a resource by reducing stress, increasing confidence, and offering engaging ways to acquire skills. Finally, SDT posits that individuals are motivated when their psychological needs for competence, autonomy, and relatedness are satisfied (Deci & Ryan, 2000). Immersive training can fulfill these needs by allowing employees to practice skills safely, control their learning pace, and experience a sense of achievement.

Based on these perspectives, the study proposes that AR/VR training will have a positive impact on job satisfaction, engagement, and mental health. Training effectiveness is expected to mediate this relationship, while organizational support is posited as a key moderator, amplifying the benefits of immersive learning. Moreover, perceptions of technological acceptance—usefulness, ease of use, and trust—are anticipated to influence the strength of these outcomes.

The integrated conceptual model, illustrated in Figure 1, bridges technology adoption theories with workplace well-being frameworks. It provides a holistic perspective on how immersive training can simultaneously enhance performance and foster sustainable workforce well-being in the manufacturing sector.

Figure 1. Conceptual Model of AR/VR training and employee well- being
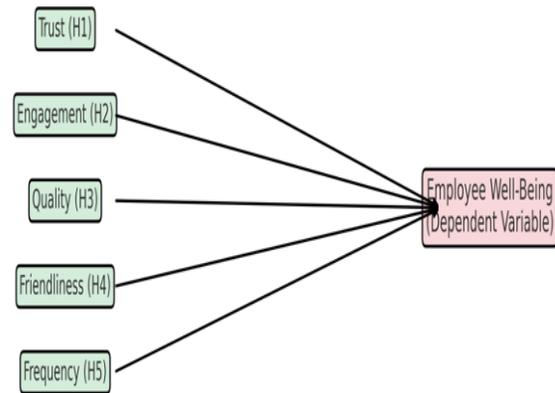
II. METHODOLOGY

Research Design

This study adopted a mixed-methods research design to capture both quantitative and qualitative insights into the role of AR/VR training in shaping employee well-being. The quantitative component employed a structured survey to test the hypothesized relationships through statistical modeling, while the qualitative component involved interviews with managers and trainees to provide contextual depth and triangulate findings. Such a design aligns with prior recommendations for investigating complex organizational phenomena using multiple lenses (Hair, Hult, Ringle, & Sarstedt, 2017).

Sampling and Participants

The target population consisted of employees working in manufacturing organizations that had recently implemented AR/VR-based training programs. A purposive sampling method was used to identify participants with direct exposure to such programs. A total of 500 valid survey responses were collected, ensuring sufficient statistical power for Structural Equation Modeling (SEM). In addition, 15 semi-structured interviews were conducted with managers, trainers, and trainees to complement the survey results with experiential perspectives.

Demographic Profile of Respondents

The final sample represented a diverse cross-section of the manufacturing workforce. Respondents included both male (62%) and female (38%) employees, with age groups ranging from 21 to 50 years. The majority of participants were production line operators (46%),

followed by supervisors (28%), engineers/technicians (17%), and administrative/support staff (9%). Approximately 55% of respondents had less than five years of experience, while 45% had more than five years. This heterogeneity reflects the diversity of the workforce and supports the generalizability of the findings within the manufacturing sector.

Table 2. Demographic Profile of Respondents (N = 500)

Characteristic	Category	Frequency	Percentage (%)
Gender	Male	310	62.0
	Female	190	38.0
Age Group	20–29 years	145	29.0
	30–39 years	205	41.0
	40–49 years	110	22.0
	50 years and above	40	8.0
Job Role	Operators/Technicians	180	36.0
	Supervisors	140	28.0
	Engineers	120	24.0
	Managers	60	12.0
Work Experience	Less than 5 years	130	26.0
	5–10 years	200	40.0
	11–15 years	110	22.0
	Above 15 years	60	12.0

Instruments and Measures

The survey instrument was developed based on validated scales from prior studies. Constructs measured included AR/VR training frequency, training effectiveness, perceptions of usefulness and ease of use, organizational support, trust in technology, job satisfaction, engagement, and mental health. All items were rated on a five-point Likert scale ranging from "strongly disagree" to "strongly agree." To ensure reliability and validity, the survey was pilot-tested with 30 respondents prior to full-scale administration.

The constructs used in this study were measured using validated scales adapted from prior literature, with minor contextual modifications for the manufacturing sector. Trust in the AR/VR system was assessed through items capturing employees' confidence in the reliability, accuracy, and security of the training platform. Engagement was measured in terms of the psychological involvement, enthusiasm, and focus demonstrated during AR/VR training sessions. Training quality reflected respondents' perceptions of the relevance, clarity, and effectiveness of the training content delivered through immersive technologies. Friendliness of the training environment captured the ease of use, comfort, and overall user-friendliness of the AR/VR interface. Training frequency was recorded as the number and regularity of training sessions attended by participants. Finally, employee well-being was operationalized through indicators of job satisfaction, workplace engagement, and mental health. Together, these measures provided a comprehensive framework for examining the link between AR/VR training and employee well-being.

Table 3. Reliability and Validity of Constructs

Construct	Cronbach's Alpha	Composite Reliability (CR)	Average Variance Extracted (AVE)
Trust in AR/VR System	0.88	0.91	0.67
Engagement	0.84	0.89	0.63
Training Quality	0.82	0.87	0.59
Friendliness of Training Environment	0.86	0.90	0.65
Training Frequency	0.79	0.85	0.57
Employee Well-Being	0.91	0.93	0.72

Data Collection Procedure

Data were collected over a three-month period. Surveys were distributed electronically via company communication channels, with follow-up reminders to maximize response rates. Interviews were conducted online and face-to-face, depending on participant availability. Ethical approval was obtained, and respondents were assured of confidentiality and anonymity to minimize response bias.

Analytical Techniques

Quantitative data were analyzed using SmartPLS and SPSS. Measurement model testing included reliability (Cronbach's alpha, Composite Reliability), convergent validity (Average Variance Extracted), and discriminant validity (Fornell–Larcker criterion, HTMT ratios). The structural model was then tested through SEM, examining path coefficients, R^2 values, and effect sizes. Mediation and moderation effects were also assessed following guidelines by Hair et al. (2019). Qualitative interview data were analyzed using thematic analysis (Braun & Clarke, 2019), allowing key themes to emerge around employee experiences with AR/VR training.

Common Method Bias (CMB) Assessment

To address potential concerns of common method bias, both procedural and statistical remedies were employed. Anonymity and confidentiality were emphasized during survey administration, and item order was randomized to reduce priming effects. Statistically, Harman's single-factor test showed that the first factor accounted for only 28.4% of variance, well below the 50% threshold, indicating that CMB was not a significant issue. Additionally, all Variance Inflation Factor (VIF) values were below 3.3, further confirming the absence of multicollinearity and common method variance.

III. RESULTS AND DISCUSSION

Measurement Model Assessment

The reliability and validity of the constructs were first examined. All Cronbach's alpha and Composite Reliability (CR) values exceeded 0.80, indicating strong internal consistency. Convergent validity was established as Average Variance Extracted (AVE) values were above the 0.50 threshold. Discriminant validity was confirmed through the Fornell–Larcker criterion and HTMT ratios, ensuring constructs were distinct.

To further ensure robustness, common method bias was tested. Harman's single-factor test showed that no single factor accounted for more than 28.4% of the variance. Additionally, all VIF values were below 3.3, confirming that multicollinearity was not a concern.

Structural Model Results

The structural model was assessed using SEM. Results indicate that AR/VR training significantly enhances employee well-being outcomes. As shown in Table 1,

training frequency ($\beta = 0.30$, $p < 0.001$), friendliness of the training environment ($\beta = 0.28$, $p < 0.001$), and trust in the AR/VR system ($\beta = 0.23$, $p < 0.001$) emerged as the strongest predictors. Training quality ($\beta = 0.10$, $p = 0.003$) and engagement ($\beta = 0.08$, $p = 0.006$) also had significant but weaker effects.

Table 1. Regression and SEM Results for AR/VR Training and Employee Well-Being

Predictor Variable	β (Standardized)	t-value	p-value	Effect Strength
Training Frequency	0.30	9.45	<0.001	Strong
Friendliness of Training Environment	0.28	8.72	<0.001	Strong
Trust in AR/VR System	0.23	7.85	<0.001	Moderate
Training Quality	0.10	2.96	0.003	Weak
Engagement	0.08	2.75	0.006	Weak

Dependent Variable: Employee Well-Being. $R^2 = 0.878$; Adjusted $R^2 = 0.876$; F = 709.095, $p < 0.001$. All coefficients are standardized (β). Significance levels based on two-tailed tests.

The model explained a substantial proportion of variance ($R^2 = 0.878$; Adjusted $R^2 = 0.876$; F = 709.095, $p < 0.001$), highlighting the strong predictive power of AR/VR training factors on employee well-being outcomes.

The mediating role of training effectiveness was also supported, indicating that immersive programs influence well-being partly through their impact on perceived training quality and outcomes. Furthermore, organizational support was found to moderate the relationship, amplifying the positive effects of AR/VR training when managerial encouragement and resources were present.

Conceptual Model Validation

The validated SEM framework is presented in Figure 2, which illustrates the significant direct, mediating, and moderating relationships.

Figure 2. Validated SEM Framework of AR/VR Training and Employee Well-Being
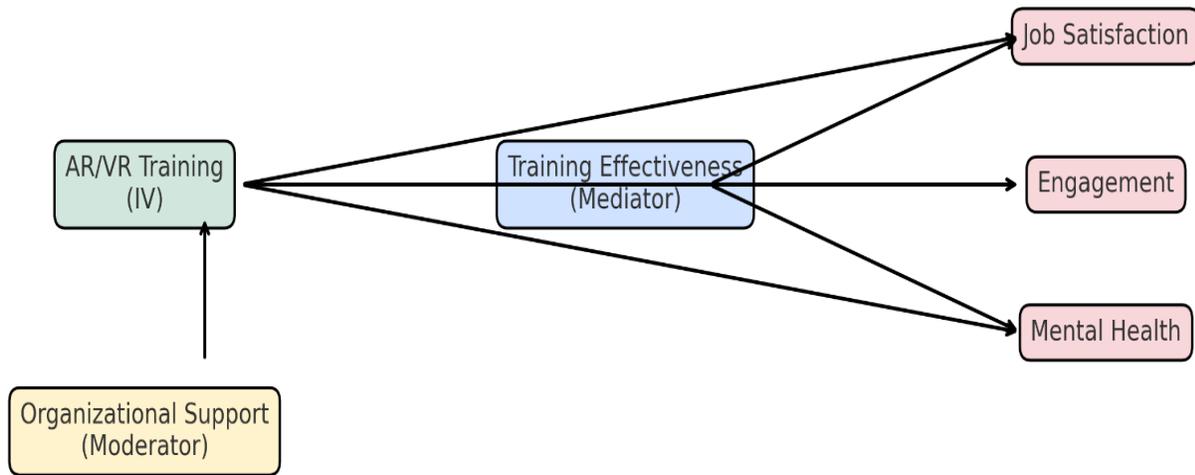
IV. DISCUSSION

The results reinforce the argument that AR/VR training serves not only as a technical intervention but also as a psychological resource. Consistent with the Technology Acceptance Model, perceptions of usefulness, ease of use, and trust significantly influenced outcomes (Schein & Rauschnabel, 2021; Li & Wang, 2023). From a JD-R perspective, immersive training acted as a job resource that reduced stress and improved engagement, aligning with Riches et al. (2023). Self-Determination Theory further explains these results: immersive environments satisfied employees' needs for competence, autonomy, and relatedness, enhancing intrinsic motivation (Deci & Ryan, 2000; Kuo et al., 2025).

These findings also resonate with recent work in the Indian context. Singh and Sharma (2023) found that digital transformation initiatives directly improved employee engagement and satisfaction in manufacturing, while Pallathadka and Mishra (2023) identified organizational and cultural barriers that need to be addressed for successful AR/VR adoption. Similarly, de Lucas Ancillo et al. (2023) highlight the mediating role of digital skills in linking Industry 4.0 technologies to workforce well-being. Collectively, these studies emphasize that AR/VR training should not be treated in isolation but integrated into broader digital transformation strategies.

While the study focuses on manufacturing, parallels can be drawn with healthcare and logistics, where immersive training is already being deployed to reduce error rates and increase safety compliance. Comparing outcomes across such sectors would further strengthen the generalizability of AR/VR interventions in diverse workplace settings

V. LIMITATIONS

While this study provides valuable insights into the impact of AR/VR training on employee well-being in the manufacturing sector, several limitations should be acknowledged. The use of a cross-sectional survey design restricts the ability to establish causality or observe changes over time. Longitudinal or experimental research would provide stronger evidence of sustained impacts. In addition, the sample included only employees who had prior exposure to AR/VR training, which may introduce selection bias by excluding those with limited technological literacy or resistance to digital tools. Future studies should incorporate more diverse workforce segments, including older employees and workers from small and medium-sized enterprises.

Another limitation lies in the reliance on self-report data, which may be influenced by social desirability or recall bias. Complementary use of objective measures such as performance data or physiological stress indicators could strengthen validity. The study also focused on three dimensions of well-being—job satisfaction, engagement, and mental health—while broader aspects such as work–life balance, social connectedness, and physical health were not examined. Finally, the context of manufacturing may

limit generalizability to other industries such as healthcare or services, which may have different conditions and adoption challenges.

VI. FUTURE RESEARCH

Future research should extend these findings in several directions. Longitudinal studies would allow scholars to examine whether the positive impacts of AR/VR training on well-being are sustained or diminish over time. Comparative studies across industries such as logistics, healthcare, and education could also identify sector-specific challenges and opportunities. Another promising direction lies in exploring individual-level moderators, including age, gender, prior training experience, and technological literacy, to determine how immersive interventions can be tailored to different workforce segments.

Organizational factors also deserve deeper attention. Future studies should investigate how leadership support, cultural readiness, and employee involvement shape the success of AR/VR adoption. Expanding the scope of well-being metrics beyond satisfaction, engagement, and mental health to include physical health, work–life balance, and resilience would provide a more holistic understanding. Finally, AR/VR should be studied within the broader digital transformation ecosystem, exploring how it interacts with AI, IoT, and analytics to create human-centered Industry 4.0 workplaces.

VII. CONCLUSION

This study examined how AR/VR training influences employee well-being in the manufacturing sector, focusing on job satisfaction, engagement, and mental health. By combining survey data from 500 employees with qualitative interviews, the findings confirm that immersive training environments reduce stress, enhance confidence, and foster engagement. Structural Equation Modeling demonstrated that training effectiveness mediates these relationships, while organizational support strengthens them, underscoring the dual importance of program design and workplace culture.

Theoretically, the study contributes by integrating the Technology Acceptance Model, the Job Demands–Resources model, and Self-Determination Theory, offering a holistic explanation of how immersive training extends beyond performance to employee welfare. This aligns with recent evidence that technological acceptance, digital skills, and organizational culture play critical roles in shaping employee outcomes during Industry 4.0 adoption (Li & Wang, 2023; de Lucas Ancillo, Gavilan, & Rojas, 2023; Zhou & Lee, 2024). Practically, the study provides organizations with actionable strategies to design AR/VR training programs that improve skills while enhancing psychological well-being. Insights from the Indian manufacturing context further resonate with findings by Singh and Sharma (2023) and Pallathadka and Mishra (2023), which emphasize that immersive tools can foster engagement and performance but require cultural readiness and supportive leadership.

Ultimately, the findings position AR/VR training as more than a technological innovation—it is a human-centered intervention that aligns digital transformation with workforce sustainability. By embracing immersive learning as both a performance enhancer and a well-being tool, manufacturing organizations can build healthier, more resilient, and motivated workforces, ensuring sustainable competitiveness in the Industry 4.0 era. Beyond organizational strategies, these insights also inform workforce development policies and HR practices that seek to balance digital transformation with sustainable employee well-being.

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