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# Augmented and Virtual Reality Training and Its Contribution to Safety Behaviour Readiness: A Descriptive Evaluation of the SMITAC Programme

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## Abstract

This study examines workforce readiness towards Augmented Reality and Virtual Reality based safety training implemented under the SMITAC programme. Despite growing interest in immersive technologies within high-risk industries, empirical evidence on user readiness in the electrical utility context remains limited. A descriptive cross-sectional evaluation was conducted involving 240 non-executive technical personnel who participated in 17 training sessions delivered at ILSAS (Selangor), Johor, and Penang. Readiness was operationalised across four perception domains, namely suitability of AR for electrical work, perceived usefulness, perceived ease of use, and organisational implementation support, measured using a five-point Likert scale. The findings indicate generally high acceptance of immersive training, with participants reporting clearer procedural understanding, reduced learning pressure, and improved task confidence following exposure to AR and VR modules. Instructor facilitation was also rated as an important supporting factor for effective learning transfer. Overall readiness scores were high across domains, suggesting favourable workforce disposition towards immersive safety training adoption. However, as the evaluation relied on self-reported perceptions and descriptive analysis, the results should be interpreted as early readiness indicators rather than evidence of behavioural change. The study provides an empirical baseline for scaling immersive training within the electrical utility sector and highlights the need for future longitudinal and Structural Equation Modeling based research incorporating objective safety performance measures.

## KEYWORDS

augmented reality; virtual reality; safety behaviour; immersive training; descriptive evaluation.

## Introduction

Safety behaviour remains a critical determinant of accident prevention in high-risk industries such as electrical utilities (Bowdler et al., 2023; Cornelissen et al., 2017; Zhang et al., 2022). Despite extensive regulatory frameworks, engineering safeguards, and procedural controls, serious incidents continue to occur, indicating that compliance driven approaches alone are insufficient to sustain safety performance (Besnard and Hollnagel, 2012; Cambon et al., 2006; Peres et al., 2020). This limitation is particularly pronounced in decentralised and field-based operations where direct supervision is constrained and workers must rely heavily on their own judgement and preparedness (Pillay, 2015; Lawani et al., 2023).

Reflecting this reality, safety science has progressively shifted from attributing accidents solely to unsafe acts towards recognising the role of organisational and psychological determinants of safe work behaviour (Hofmann et al., 2017). While early models emphasised procedural violations (Heinrich, 1931), later frameworks highlighted the importance of safety climate, leadership, and system defences (Reason, 1997). More recent work points to proximal readiness factors, particularly cognitive clarity, safety motivation, and self-efficacy, as critical enabling conditions that shape how workers perform under risk (Carra et al., 2024).

In parallel, immersive technologies such as Augmented Reality and Virtual Reality have gained momentum in industrial training due to their capacity to simulate hazardous tasks in controlled environments (Cordeiro et al., 2025; Fleury et al., 2023; Smirnova et al., 2020). Immersive training allows repeated procedural rehearsal without real world exposure, with reported benefits in engagement, hazard awareness, and procedural understanding. However, robust evidence linking immersive training to downstream safety behaviour in real operational settings remains limited, with much of the existing literature relying on student samples or laboratory simulations (Scorgie et al., 2023)(Hou et al., 2017; Kassem et al., 2017).

This study advances the field in three ways. Contextually, it examines immersive training within an operational utility environment through the Smart Mobile Immersive Training Assessment Centre implemented at ILSAS (Selangor), involving experienced non-executive electrical personnel rather than novice or academic samples. Conceptually, the study focuses on readiness antecedents, specifically perceived cognitive clarity, reduced learning pressure, task confidence or safety self-efficacy, and instructor facilitation, as proximal mechanisms bridging immersive exposure and safety behaviour readiness. Practically, it evaluates user acceptance, usability, and preferred learning mode to inform whether immersive technologies should complement rather than replace trainer led delivery in safety critical training ecosystems.

Accordingly, this study aims to (1) determine the level of acceptance and perceived learning impact of SMITAC AR and VR training among non-executive electrical personnel, and (2) identify the readiness related antecedents most strongly endorsed following immersive exposure. By establishing an empirical baseline within a real utility training context, the study provides evidence to support more targeted and scalable deployment of immersive safety training in high-risk industrial environments.

### Safety Behaviour and Training Interventions

Safety behaviour is commonly conceptualised as comprising safety compliance and safety participation (Neal & Griffin, 2006). Safety compliance refers to adherence to rules and procedures, whereas safety participation involves discretionary actions that support a safe working environment. Research consistently shows that safety behaviour is influenced by proximal psychological factors such as hazard recognition capability, safety motivation, and self-efficacy, rather than by rules alone (Griffin & Neal, 2000). Studies indicate that interventions directed at the group or organisational level are often more effective in preventing accidents than those focused solely on the individual (Dyreborg et al., 2022).

Training is widely recognised as a key organisational

intervention for strengthening these antecedents. However, traditional training approaches are often constrained by the inability to safely replicate hazardous conditions, particularly in industries involving live electrical equipment. This can limit the effectiveness of training in fostering preparedness for real-world risks.

### Immersive Technologies in Safety Training

Recent reviews of immersive safety training indicate that AR and VR technologies can enhance learning by providing realistic, interactive, and repeatable practice opportunities (Cordeiro et al., 2025). Studies in industrial and engineering contexts report improvements in perceived understanding, engagement, and confidence following immersive training (Peña-Ríos et al., 2018), although most evaluations often focus on learning outcomes rather than observable workplace behaviour (Scorgie et al., 2023). Immersive training systems have the potential to be effective cognitive tools for learning, improving memory recall, and understanding, and accelerating the learning curve in real-world scenarios (Peña Ríos et al., 2018).

Importantly, contemporary literature positions immersive training as most effective when implemented within blended learning models supported by instructors. Instructor facilitation is critical for contextualising simulation experiences and reinforcing correct judgement in safety-critical tasks.

### Descriptive Evaluation of Training Innovations

Descriptive programme evaluation is widely accepted as an appropriate methodological approach for assessing new or pilot training initiatives. Such evaluations aim to document acceptance, feasibility, and perceived effectiveness before advancing to inferential or longitudinal designs. In organisational settings, descriptive evidence provides valuable input for decision-making regarding scaling, refinement, and future research.

## Methods

### Study Design

This study employed a descriptive cross sectional evaluation design to examine participants perceptions of Augmented Reality and Virtual Reality based training delivered through the SMITAC programme. Cross sectional designs are appropriate for capturing perceptual responses at a single point in time without manipulating variables (Slater and Hasson, 2024). Such designs are widely used in technology enhanced learning research to profile user acceptance and readiness in authentic training environments (Radianti et al., 2020).

Consistent with the exploratory purpose of this study, the evaluation focused on acceptance, perceived learning support, and readiness outcomes rather than testing causal relationships between training exposure and behavioural change. This limitation is inherent in cross sectional perceptual studies and is acknowledged in the interpretation of findings (Gubbins and Rousseau, 2015; Slater and Hasson, 2024).

### Participants and Training Context

The evaluation involved 240 executive and non-executive technical personnel who attended 17 SMITAC training sessions conducted at three locations, namely ILSAS (Selangor), Johor, and Penang. The training focused

on safety critical electrical operations involving medium voltage equipment and was delivered using instructor facilitated immersive technologies.

#### Sampling approach

Participants were recruited using a census approach of all trainees who attended the scheduled SMITAC sessions during the data collection period. Inclusion criteria required participants to:

1. non-executive technical personnel
2. have completed the AR and VR training session
3. provide voluntary consent

No additional exclusion criteria were imposed except for incomplete questionnaire responses. Because the survey was administered immediately after training, the response rate was high; however, participation remained voluntary.

This sampling frame is consistent with immersive training evaluations where the target population comprises operational personnel directly exposed to the learning intervention (Borsci et al., 2014; Radianti et al., 2020).

#### Instrument and Construct Operationalisation

A structured questionnaire was developed to assess workforce readiness and acceptance of Augmented Reality for electrical training. The instrument consisted of four multi item constructs grounded in established technology acceptance frameworks.

#### Construct structure

The questionnaire comprised sixteen perception items distributed across four constructs:

1. Suitability of AR for electrical work: 4 items
2. Expected benefits or perceived usefulness: 4 items
3. Expected ease of use: 4 items

Organisational support and implementation readiness: 4 items

All items were measured using a five-point Likert scale ranging from 1 strongly disagree to 5 strongly agree. Construct scores were computed as the mean of their respective items, with higher scores indicating stronger readiness or acceptance.

#### Construct definitions and example items

Suitability of AR for electrical work refers to the perceived appropriateness of Augmented Reality for supporting safety critical electrical training tasks. An example item is: "AR is suitable for high risk electrical training." This construct reflects the task technology fit perspective in immersive learning environments (Bacca et al., 2014; Radianti et al., 2020).

Expected benefits or perceived usefulness represents the degree to which AR is believed to enhance learning effectiveness and work preparedness. An example item is: "AR can improve my understanding of SOP and work procedures." This construct was conceptually adapted from the Technology Acceptance Model (Davis, 1989).

Expected ease of use refers to the perceived effort required to learn and operate AR systems. An example item is: "I believe AR will be easy for technical workers to learn." This dimension is also derived from the Technology Acceptance Model (Davis, 1989).

Organisational support and implementation readiness captures the perceived availability of resources, infrastructure, and managerial support for AR deployment. An example item is: "My organisation is capable of providing the equipment and support for AR." This construct aligns with facilitating conditions and social influence dimensions within the Unified Theory of

Acceptance and Use of Technology (Venkatesh et al., 2003).

#### Reliability Assessment

Internal consistency reliability was evaluated using Cronbach alpha for each multi item construct based on the study dataset. The results indicated that the Suitability of AR for electrical work construct demonstrated excellent internal consistency (alpha = 0.98). The remaining constructs showed moderate reliability, namely Expected benefits or perceived usefulness (alpha = 0.63), Expected ease of use (alpha = 0.64), and Organisational support and implementation readiness (alpha = 0.64).

Although three constructs recorded alpha values slightly below the conventional threshold of 0.70, these values are considered acceptable for preliminary exploratory studies involving newly contextualised instruments (Taber, 2018). Given that the present study aims to provide an initial descriptive assessment of workforce readiness rather than full scale instrument validation, the reliability levels were deemed sufficient for subsequent descriptive analysis.

#### Data Collection Procedure

Data were collected using a self-administered questionnaire distributed immediately after completion of the training sessions. Likert based instruments are widely used for assessing perceptions and attitudes in educational and training research (Sullivan & Artino, 2013). Participation was voluntary and no identifying information was collected. Completed responses were compiled into a secure dataset for analysis.

#### Ethics and Confidentiality

The evaluation was conducted as part of an internal training effectiveness review. Participants were informed about the purpose of the study and provided voluntary consent prior to questionnaire completion. Responses were collected anonymously and reported only in aggregate form to protect confidentiality. No personal identifiers were retained in the analytical dataset.

#### Bias Control Measures

Several procedural steps were implemented to minimise potential response bias associated with self report evaluations. First, questionnaires were completed anonymously. Second, instructors were not present during response completion. Third, neutral wording was used for all perception items. Finally, respondents were informed that results would be reported only in aggregate form. These measures are recommended to reduce social desirability bias in organisational surveys (Gunnell et al., 2019).

#### Data Analysis

Descriptive statistics were used to summarise participant responses. Frequencies and percentages were reported for categorical variables, while means and standard deviations were calculated for perception items and construct scores. This approach is appropriate for preliminary readiness assessments and provides an overall profile of workforce acceptance of AR based training (Fernandez Castilla et al., 2024).

## Result and Discussion

The sample comprised participants from training sessions conducted across three locations, namely Selangor, Johor, and Penang, involving a total of 17 sessions. On average, each session was attended by

Table 1. Descriptive Result

Item	Mean	SD
B1	4.713	0.480
B2	4.700	0.486
B3	4.713	0.480
B4	4.704	0.484
B5	3.904	0.794
B6	3.925	0.794
B7	4.713	0.480
B8	4.700	0.486
B9	4.713	0.480
B10	3.904	0.794
B11	3.925	0.794
B12	4.704	0.484
B13	3.904	0.794
B14	4.713	0.480
B15	4.700	0.486
B16	4.713	0.480

approximately 20 to 25 participants. The demographic profile indicates that the respondents were predominantly male (98 percent) and entirely from the non-executive employment category, reflecting the operational focus of the SMITAC programme.

In terms of age distribution, most participants were between 31 and 40 years old (68 percent), followed by those aged 41 to 50 years (23 percent), indicating a largely mid-career technical workforce. Most respondents held diploma level qualifications (68 percent), with smaller proportions holding certificate level (23 percent) and bachelor's degree qualifications (5 percent).

Ethnically, the sample was primarily Malay (65 percent), followed by Chinese (28 percent) and Indian (6 percent). Regarding work experience, the largest group had between 11 and 15 years of service (46 percent), suggesting substantial field exposure among participants. Nearly all respondents (99 percent) had previously attended ILSAS training, and the majority reported that their most recent course was technical in nature. Overall, the sample represents an experienced and technically oriented workforce suitable for evaluating immersive safety training initiatives.

Summary of Descriptive Results

Table 1 summarises the descriptive statistics for the sixteen readiness items measuring workforce acceptance of Augmented Reality for electrical training. Overall, the findings demonstrate a strong positive perception among respondents. Most items recorded high mean scores exceeding 4.70, with relatively low standard deviations of approximately 0.48, indicating a high level of agreement and response stability across the sample.

Items associated with the suitability of AR for safety critical electrical work were consistently rated the highest. Respondents strongly agreed that AR is appropriate for high risk training environments, procedural learning, and hazard related applications. This pattern suggests that technical personnel clearly recognise the functional relevance of immersive technologies within the electrical utility training context.

However, a small cluster of items recorded comparatively lower mean values, namely B5, B6, B10, B11, and B13. These items showed mean scores around 3.90 and higher standard deviations of approximately 0.79, indicating greater variability in responses. These items are

primarily linked to perceived usefulness confidence, ease of use expectations, and organisational readiness. The dispersion suggests that while conceptual acceptance is high, some respondents remain cautious regarding practical usability and organisational preparedness.

The overall readiness pattern is further illustrated in Figure 1, which presents the radar profile of all measurement items. The radar shape exhibits a broadly expanded profile, confirming strong acceptance across most domains. Nevertheless, slight inward contraction is observable in the perceived usefulness and organisational support dimensions, consistent with the descriptive statistics reported in Table 1.

Collectively, the descriptive results indicate that the workforce demonstrates strong initial readiness for AR enabled electrical training. At the same time, the relatively lower scores in usability confidence and organisational support highlight specific areas that may benefit from targeted implementation strategies during the early deployment phase.

The descriptive findings provide important preliminary insight into workforce readiness for Augmented Reality enabled electrical training. The consistently high ratings for suitability related items indicate that technical personnel clearly perceive strong task relevance of AR for safety critical electrical operations. This observation aligns with the task technology fit perspective, which posits that technology adoption is more likely when users perceive a strong match between technological capabilities and job requirements (Bacca et al., 2014; Radianti et al., 2020).

From the technology acceptance standpoint, the strong overall readiness profile is broadly consistent with the Technology Acceptance Model, which emphasises perceived usefulness and perceived ease of use as primary drivers of user acceptance (Davis, 1989). The high mean scores across most items suggest that the workforce already demonstrates favourable cognitive predispositions towards immersive training technologies

However, the comparatively lower scores observed in selected items related to perceived usefulness nuance, ease of use confidence, and organisational readiness provide an important diagnostic signal. In line with the Unified Theory of Acceptance and Use of Technology, facilitating conditions and user effort expectations remain critical enabling factors that can influence actual adoption

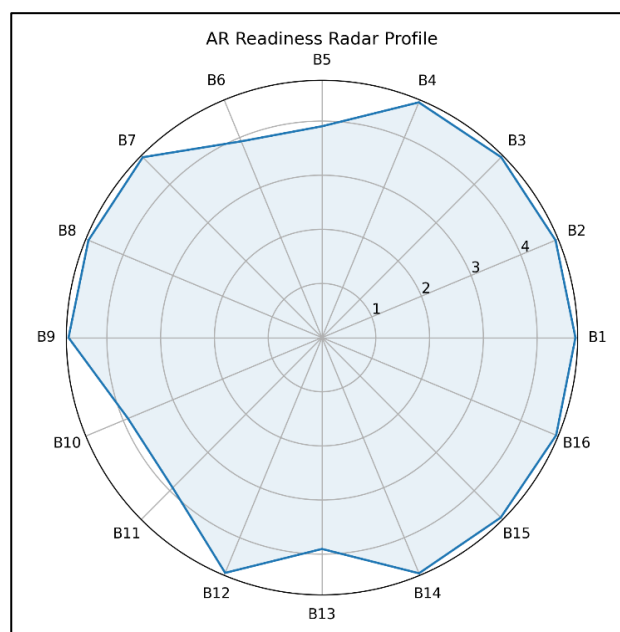


Figure 1. AR Readiness Radar Profile

behaviour (Venkatesh et al., 2003). This suggests that while conceptual acceptance of AR is strong within the SMITAC context, successful large scale implementation will likely depend on targeted user familiarisation, usability assurance, and organisational readiness initiatives.

Taken together, the findings position AR based training as a highly promising innovation for the electrical utility training ecosystem, while simultaneously highlighting specific readiness dimensions that warrant strategic attention during the early deployment phase.

#### Contribution of Immersive Training to Safety Behaviour Readiness

This study provides preliminary but important evidence on workforce readiness for immersive training within the SMITAC programme. The descriptive results indicate strong acceptance among experienced non-executive technical personnel. Despite limited prior exposure to immersive technologies, participants reported clearer procedural understanding, reduced learning pressure, and improved task confidence following AR and VR training. These findings are consistent with recent studies demonstrating that immersive environments enhance learning engagement and self-efficacy in technical training contexts (Mousavi et al., 2023; Rizquallah et al., 2024).

From a safety perspective, the observed improvements are theoretically meaningful. Enhanced procedural clarity and reduced cognitive strain are associated with stronger cognitive readiness for safe task execution (Nykänen et al., 2021). Likewise, increased confidence reflects elevated safety self-efficacy, a well-established predictor of both safety compliance and safety participation behaviours (Choi, 2017; Clarke, 2006). Rather than directly altering behaviour, the present findings suggest that immersive training strengthens upstream psychological conditions that enable safer performance in operational settings.

The continued preference for instructor facilitation further indicates that immersive technologies function most effectively within a blended learning architecture. This aligns with emerging evidence that instructor guided immersive learning enhances contextual judgement and transfer of training in safety critical domains (Bizami et al., 2022; Lehtikko et al., 2024; Peng, 2023). For the electrical

utility sector, a hybrid delivery model appears to be the most pragmatic pathway for scaling immersive safety capability.

Overall, the results position AR and VR based training as a strategically promising intervention for strengthening safety behaviour readiness. However, the findings should be interpreted as perceptual readiness indicators rather than direct evidence of behavioural change.

#### Limitations And Future Research

Several limitations warrant consideration. First, the study relied on self-reported perceptions and descriptive analysis, which restrict causal inference. Self-report data are inherently vulnerable to social desirability and response bias (Gunnell et al., 2019; Vilppu et al., 2019). Second, the evaluation captured immediate post training reactions rather than longitudinal safety outcomes, which limits conclusions regarding training transfer (Nielsen et al., 2021).

Future research should adopt longitudinal and inferential designs incorporating objective safety indicators such as procedural errors, near miss reports, and supervisory observations (Gao et al., 2022). Structural Equation Modeling is particularly recommended to validate the proposed readiness pathway, beginning with Confirmatory Factor Analysis for measurement validation followed by structural model testing using established goodness of fit indices (Hair et al., 2021; Hu & Bentler, 1999).

In addition, bootstrapping procedures should be employed to examine the mediating role of psychological mechanisms such as safety self-efficacy, while multi group SEM may assess model stability across operational contexts. Addressing these methodological extensions will provide stronger empirical grounding for immersive safety training deployment in high-risk industries.

## Conclusion

This study provides preliminary evidence that immersive AR and VR training within the SMITAC programme is well received by experienced electrical personnel. Participants reported clearer procedural understanding, reduced learning pressure, and improved

task confidence, indicating strong readiness for immersive safety training adoption.

The findings suggest that immersive technologies primarily strengthen psychological readiness, particularly cognitive preparedness and safety self-efficacy, rather than directly changing behaviour. The continued preference for instructor support further underscores the importance of a blended training architecture in safety critical domains.

While the results support the strategic potential of immersive training for the electrical utility sector, they remain perceptual and cross sectional in nature. Future longitudinal studies using Structural Equation Modeling and objective safety indicators are necessary to verify behavioural impact.

Overall, this study establishes an empirical baseline for scaling immersive training within utility workforce development and provides a foundation for more rigorous validation in high risk industrial settings.

## Author contributions

All authors contributed to the study conception and

design. The first author led the data collection, analysis, and manuscript preparation. Co-authors contributed to the interpretation of findings and critically reviewed the manuscript. All authors approved the final version of the manuscript.

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