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Game-changing the way to teach professional maintenance in company-specific production systems

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Abstract

Purpose – Effective knowledge transfer in multi-site organizations using a company-specific production system (XPS) in environments with pervasive digital technologies relies on understanding diverse learning preferences. This study examines the integration of mobile micro-learning and gamified elements into the professional maintenance (PM) education framework of a Scandinavian automotive company, aiming to address limited instructor availability and improve engagement.

Design/methodology/approach – A sequential mixed-method approach was conducted in three phases. The first phase involved a pre-study with interviews to gather maintenance directors' strategic perspectives, complemented by questionnaires from maintenance blue-collar (technicians and engineers) and white-collar (managers) staff to identify current challenges in maintenance education. In the second phase, a questionnaire collected key inputs for designing an application, which was validated through a proof of concept. The third and final phase evaluated user engagement, training usefulness and satisfaction, using performance metrics for assessment.

Findings – Gamified elements enhance employee engagement by creating a competitive and interactive learning environment, leading to higher user satisfaction. The platform's flexibility supports self-paced learning for a global workforce and addresses translation issues. The study concludes that mobile learning should complement classroom training, as it improves overall training effectiveness by providing continuous learning opportunities and standardized, engaging solutions, filling gaps in industrial maintenance departments.

Originality/value – While E-learning, mobile compatibility, gamification, microlearning, spaced repetition, interactivity and collaboration are commonly discussed in corporate education, their combined integration into PM education and training for XPS has not been addressed.

Keywords Maintenance, Manufacturing, Production, Education, Gamification, XPS

Paper type Research article

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1. Introduction

The rapid shifts in technological, economic and social patterns demand new strategies for lifelong learning, particularly in workplace education (Torresan and Hinterhuber, 2023). In organizations, effective knowledge retention (Shail, 2019) and transfer (Dar and Bhat, 2016) are essential for boosting productivity and ensuring longevity, since this learning capability is the core that leads to continuous improvement (Hekneby and Powell, 2023). Additionally, since most employees in the manufacturing sector are beyond the typical education age (Calzavara *et al*., 2020), traditional teaching methods prove insufficient (Papathanassiou and Emmanouilidis, 2010) as training in this field is often constrained by time (Sherwin, 2000) and space limitations, making conventional methods impractical (Emmanouilidis and Spais, 2010). The emerging phenomenon of digitalized industries demands adaptation to support this technological change (Lundgren *et al*., 2022) in the maintenance of manufacturing plants in environments with pervasive digital technologies, defined as Smart Maintenance (Bokrantz *et al*., 2020), where data-driven decision-making and human capital resources are two of the four core dimensions.

In addition, to address different learning preferences, training must be flexible and adaptable to real-time tasks, particularly through digital tools (Papathanassiou and Emmanouilidis, 2010), especially mobile learning platforms incorporating micro-content and gamification. On one hand, mobile learning provides flexible, user-centered content delivery via short, targeted information (Buchem and Hamelmann, 2010), enabling learning anywhere and anytime (Souza and do Amaral, 2014). On the other hand, it allows standardized knowledge assessment, being cost-effective, time-efficient and easily updatable (Emmanouilidis and Spais, 2010).

While previous studies have explored the potential of mobile and micro-learning to enhance motivation and engagement in engineering and business, this research focuses on their application in professional maintenance (PM) education within the company-specific production system (XPS), the reason is that classical delivery of training in maintenance usually lacks flexibility in terms of time and location, which hinders performing recurrent and long-duration training sessions, negatively impacting knowledge retention. Alternative ways of managing knowledge for maintenance personnel at the right level (Roham and Gomes, 2024) need to adapt to this scenario; therefore, the training itself needs to turn flexible (Papathanassiou and Emmanouilidis, 2010) and digitalization is one way to support this shift through E-learning platforms. Two research questions were formulated to guide this study, while

RQ1. Which features should be included in an application to improve maintenance staff education satisfaction at a multi-site global manufacturing company? and

RQ2. How maintenance workers perceive the usefulness, ease of use and learning, and satisfaction of a proposed App platform for PM education?

This article aims to include the features of E-learning, microcontent, spaced repetition and gamification in a mobile-compatible platform through the launch of an application, to increase interactivity and collaboration for maintenance practitioners of a multi-site global manufacturing organization and validate user's usefulness, ease of use and ease of learning which links to users' increased satisfaction in comparison to traditional classroom instructor-led training as part of the journey toward Smart Maintenance.

2. Theoretical background

2.1 Education and training in maintenance

Engineers who begin their careers in maintenance-related roles feel less prepared to make good decisions and judgments related to their new profession, which demands additional specialization focused on maintenance (Kans, 2021). At the same time, when starting their

careers, these engineers encounter a lack of instructor availability as well as restrictions on dedicated and uninterrupted time for training, since specific maintenance skills are obtained through time-consuming on-the-job training and experience (Maurer *et al*., 2003).

Learning how to learn maintenance skills in this scenario demands creativity and innovation, and in a Smart Manufacturing context, digital tools can provide a solution encompassing mobile compatibility (Beinke *et al*., 2017; Papathanasiou *et al*., 2012) associated with micro content (Di Pasquale *et al*., 2024) and gamification (Isik *et al*., 2024; Jooste *et al*., 2020). This was the motivation to map scientific papers related to these topics, resulting in the compilation of Table 1, where empirical studies stand for the collection and analysis of real-world data to evaluate the effectiveness of training methods and educational programs (Creswell and Creswell, 2017), while conceptual studies stand for the development of theoretical models to understand how specific challenges, such as emerging technologies or skill gaps, impact continuous education (Whetten, 1989).

After a full reading of the papers, the most relevant terms cited, E-learning stands out first, followed by mobile compatibility, gamification, and microlearning, including spaced repetition. There were mentions of interactivity and collaboration, but not a single paper was found including all these features for maintenance education/training purposes.

2.2 Corporate education

Industries have been facing challenges in fulfilling the demands of highly skilled maintenance workers regarding education and training (Braun *et al*., 2024; Knezevic, 1997; Tsang, 2022). Nevertheless, E-learning has become increasingly valuable in modern workforce environments for delivering standardized and engaging content (Jayanthi *et al*., 2023). It has transformed employee education by incorporating digital devices, self-paced learning and collaborative approaches (Karlsen *et al*., 2023). By aligning organizational goals with knowledge transfer (Roham and Gomes, 2024), E-learning enhances the knowledge base, improves employee satisfaction and develops competencies in a self-paced and personalized manner (Bondar *et al*., 2020; Gavril *et al*., 2017). It also allows for the re-engineering of

Table 1. Papers found regarding education and training focused on maintenance

Source	Method	Description
Papathanasiou *et al.* (2012)	Empirical	Analyses how to integrate E-learning and e-support into an e-maintenance system
Emmanouilidis *et al.* (2010)	Empirical	How to learn from users of a pilot testing for Maintenance E-learning and e-competence assessment system
Jooste *et al.* (2020)	Empirical	How to teach maintenance plan concepts in a learning factory environment mixing gamification and classroom
Papathanassiou and Emmanouilidis (2010)	Empirical	How to employ E-learning to deliver customized maintenance management training with learning evaluation
Di Pasquale *et al.* (2024)	Conceptual	How prescriptive analytics and cognitive-based learning models enhance and improve maintenance training
Emmanouilidis and Spais (2010)	Empirical	How to use e-training to enhance maintenance-related knowledge and competence
Kans (2021)	Empirical	Suggests that engineers who join maintenance roles feel less prepared, demanding additional specific education
Isik *et al.* (2024)	Conceptual	How to provide immersive and engaging learning experiences via Extended Reality for maintenance workers
Costello *et al.* (2019)	Empirical	How to develop and implement in-house low-cost, extensive maintenance training programs for medical devices
Beinke *et al.* (2017)	Conceptual	How to improve the qualification of service technicians via text-mining identification of needs and mobile gamification

training processes, offering benefits such as cost-effectiveness (Dereń *et al*., 2022), flexibility for employees (Rutar and Mestrovic, 2011) and standardized content (Zhang and Xu, 2013). Learning systems that support adaptive, personalized and collaborative learning are essential for the effective implementation of technology-enhanced learning (TEL) in organizations (Wang *et al*., 2011).

However, learning modules for employee training should carefully consider the target users and their needs to create an attractive, interactive and motivating learning experience (Al-Amri *et al*., 2020), which can be addressed via mobile learning. This includes using mobile devices to facilitate learning activities and has been recognized as a versatile approach, allowing the creation, sharing and consumption of educational content (Ojokoh *et al*., 2013). Integrating mobile learning into corporate training is crucial as it enhances E-learning programs by utilizing employees' smartphones (Macdonald and Chiu, 2011). In addition to providing convenience and accessibility, it enables self-paced learning, which has been shown to improve learning outcomes and technology adoption among employees (Dar and Bhat, 2016). Mobile learning has a positive impact on employee performance, emphasizing the importance of self-reflection, personal proximity, mobility, connectivity and spontaneity in supporting learning activities (Pimmer and Gröhbiel, 2008).

Nevertheless, converting traditional education content into a mobile-compatible format requires some adaptation to cover employees' current desire for control over their learning and preferences for short, need-based content (Karlsen *et al*., 2023; Pimmer and Gröhbiel, 2008). In response to these needs, microlearning has become a useful approach for rapid adaptation to new technical competencies. Microlearning modules offer clear, concise and well-designed single-learning topics that employees can fit in between tasks when they have available time (Emerson and Berge, 2018). These modules focus on narrow topics and prioritize technical functionality, usability and instructional flow to enhance the learning experience (Jahnke *et al*., 2020). It encourages small feedback loops and instant reflection, empowering learners to engage autonomously with bite-sized informational materials (Tanner and Preiksaitis, 2023).

Nanjappa *et al*. (2023) suggest that the microcontent should be divided into three phases. First, introduction (topic outline, problem definition, task description); second, activity (exercise, problem-solving, text-writing); and third, closing (discussion, reflection, feedback). Reviewing the content multiple times for efficient memorization and skill practice refers to spaced repetition (Sinha, 2019). This technique has been applied in various fields to optimize learning and enhance long-term employee retention (Kim *et al*., 2019). In the context of workplace training, spaced retrieval has been found to significantly improve knowledge retention, with optimal spacing increasing as the retention interval increases (Kondratjew and Kahrens, 2019). The challenge that remains regards how to get people to engage with these techniques, which connect to gamification.

Gamification involves using game mechanics and dynamics to promote learning and enhance engagement in a non-game setting (Butgereit, 2016; Göschlberger and Bruck, 2017; Kapp, 2012; Spanellis and Pyrko, 2021). In addition, it utilizes reward systems such as leaderboards, badges, points or levels to promote a sense of competition among users (Christopoulos and Mystakidis, 2023). Numerous studies have examined gamification for the workforce, with Zribi (Donath *et al*., 2020) and Swacha (Swacha and Baszuro, 2013) proposing gamified E-learning platforms. Both studies underscore gamification's potential to boost engagement and motivation. Shi *et al*. (2017) review the effects and challenges of gamification in E-learning, highlighting its ability to improve performance and provide an engaging learning experience. Furthermore, Donath *et al*. (2020) expand on this discussion by incorporating gamification techniques into E-learning platforms for sustainable development education to engage learners.

In a workforce setting, gamification techniques like leaderboards and rewards initiate competition and foster feelings of accomplishment and advancement. Additionally, collaborative activities, such as forums and scenario-based assignments, enhance peer-driven educational experiences (Christopoulos and Mystakidis, 2023), promoting engagement and behavioral change towards continuous learning in the workforce (Markopoulos *et al*., 2015;

Vargas-Macías *et al*., 2020), although it may not necessarily lead to increased learning sessions (Göschlberger and Bruck, 2017).

3. Methodology

3.1 Research approach

The study was conducted within a large multinational Scandinavian corporation operating in the heavy vehicle manufacturing sector, with a global footprint and significant production facilities primarily across Europe and the Americas. This organization utilizes a proprietary XPS that integrates production, quality and maintenance management among others. While the specific name of the company cannot be disclosed due to confidentiality agreements, this context is crucial for understanding the operational complexity and the specific environment in which the gamified mobile microlearning solution was developed and evaluated. The company employs over 100,000 individuals worldwide, with its maintenance teams of about 2,000 individuals being critical to ensuring continuous production in a highly automated environment. The research focused on their powertrain area, where training on the XPS, focused on maintenance, is paramount for operational efficiency.

This study employs a sequential mixed-methods design (Creswell and Creswell, 2017), integrating qualitative and quantitative research methodologies to provide a comprehensive understanding of current training practices within the company. The overall structure includes three consecutive phases, as shown in Figure 1.

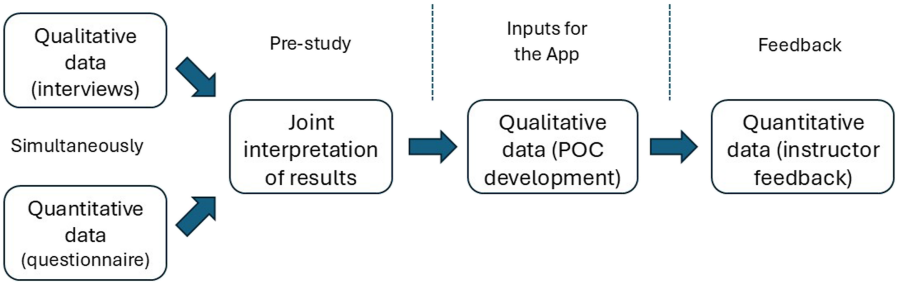

Figure 1. Overall Sequential Mixed-Methods Design with Convergent Pre-Study

A pre-study adopting a convergent mixed-methods design, where qualitative and quantitative data were collected and analyzed concurrently to capture strategic and operational perspectives is followed by the design of the Proof of Concept (POC), informed by the pre-study findings, and lately a feedback phase, in which instructors evaluated the gamified mobile learning application. This structure aligns with the definition in Creswell and Creswell (2017) definition of an explanatory sequential mixed-methods design, where distinct phases build upon each other, while the pre-study phase follows a convergent parallel approach to integrate different perspectives.

Following this methodological structure, the gamified approach was implemented through the launch of a mobile application designed as a proof of concept. This application specifically targeted the reactive phase of PM content, incorporating mobile micro-learning and gamified elements. Subsequently, the App was tested with maintenance instructors, and their feedback was collected and analyzed to facilitate knowledge transfer and retention. Qualitative and quantitative insights were derived from this evaluation, being further communicated in Section 4 Results.

3.2 Data collection

A pre-study phase was conducted before the application design phase, aiming to assess the current state of employees' training practices and perceptions in combination with a second

phase to collect desired features to implement a mobile learning platform within the company, ending in a third phase for feedback data collection, considering the target users and their needs to create an engaging, interactive and motivating learning path (Al-Amri *et al.*, 2020).

The first step included seven semi-structured interviews with maintenance directors across five facilities to collect qualitative data from a strategic perspective from the current educational program, according to the semi-structured interview questionnaire for maintenance directors in Appendix 1. Furthermore, a questionnaire was electronically administered to maximize reach and participation rates, given that participants are in different countries, to white (maintenance managers) and blue-collar (maintenance engineers, technicians and operators) employees, covering respectively tactical and operational perspectives ($N = 46$) until 30 full responses were reached. Table 2 provides an overview of the respondents' roles, work experience and percentages.

Table 2. Respondents' roles (above) and experience (below) for both the pre-study and App inputs

Role description	Respondents per role	Percentage
Electrician and/or Mechanic	5	17
Technician (Electrical and/or Mechanical)	13	43
Engineer (Electrical and/or Mechanical)	9	30
Manager	3	10
Total	30	100

Current role [years]	Respondents	Percentage
1–3	13	43
4–5	4	13
6+	13	43
Total	30	100

The second step collected inputs to design the application via questionnaire, following the same sample according to the pre-study questionnaire for maintenance employees in Appendix 2. Features connected to interactivity, collaboration, engagement, understanding, satisfaction, feedback, flexibility, technologies, challenges and limitations were collected, embracing the feasibility and potential impact of implementing a mobile learning platform, ending in the proposed POC.

Finally, the third step involved a third questionnaire to collect user feedback (Patton, 2002), in this case, current instructors, on the developed application (see Appendix 3). This questionnaire was distributed to ten participants, achieving eight complete and detailed responses. The target participants were specifically maintenance engineers and analysts, selected for their direct involvement in shaping the existing educational program as instructors and for their deep understanding of current training challenges and the necessary improvements to enhance knowledge retention. While the sample size of eight full responses is limited, these participants represent key experts within our highly specialized industrial context (XPS). Their rich, in-depth qualitative feedback was instrumental for the iterative refinement of the gamified microlearning solution, providing critical proof of concept validation and practical applicability insights essential for this applied research.

3.3 Data analysis

The first step concerning the qualitative data analysis in the pre-study followed four out of six steps inspired by the thematic analysis in Naeem *et al.* (2023) serving as a roadmap to meticulously process qualitative data. The first step concerns transcript creation and data

familiarization; the second step, keyword identification; the third step (intrinsic), code selection; and the fourth step, theme development, presented in Table 3.

Additionally, a statistical analysis was performed in parallel with the qualitative data analysis mentioned, which contemplates three key variables: employees' current training experience with the methodology, learning outcomes and satisfaction levels. The data were computed to provide insights into the central tendency (mean) and variability (standard deviation) of user ratings across various dimensions, highlighting strengths, common perceptions and areas for improvement using validated seven-point Likert scales (1 – strongly disagree or dissatisfied to 7 – strongly agree or satisfied).

For the second phase, the analysis of the inputs for engagement and flexibility in using prospective mobile learning tools for designing the App was similarly done through a statistical analysis, resulting in insights into the central tendency and variability, highlighting strengths, common perceptions and areas for attention during the App design phase. The same seven-point Likert scale was used here.

Finally, for the third step of data analysis, the USE questionnaire, developed by Lund (2001), has proven to be a valid and widely adopted evaluation tool in various studies (Hariyanto *et al*., 2020; Machado Faria *et al*., 2016). USE stands for Usefulness (anything that helps users get closer to or meet their goals), Ease of Use (how easily users can use a product) and Ease of Learning (how easily users can learn to use the tool) (Jegundo *et al*., 2020). These studies aimed to evaluate and summarize the acceptance and potential continued use of novel digital learning interfaces based on perceived usability and user satisfaction during interaction. This questionnaire used validated Likert scales, adjusted from seven to five points (1 – strongly disagree or dissatisfied to 5 – strongly agree or satisfied) to measure the specified variables related to the platform's effectiveness and user experience. Additionally, an open-ended question was included at the end of the questionnaire, allowing participants to provide comments based on their experiences. These comments, constituting qualitative data, complemented the primary quantitative analysis.

Table 3. Thematic analysis for the semi-structured interviews with maintenance directors

Training and development challenges and needs Transcription creation (1st step) and keyword identification (2nd step)	Themes (4th step)
• Overcoming challenges associated with mindset change and technological adoption • Challenges in methodological training, accessibility of training materials, and validation of competence • Need for integration and optimization of learning processes within the organization	Challenges in training and development
• Embracing discomfort and promoting self-learning • Empowering employees through first-line managers • Balancing E-learning with communal learning • Creating a more interactive and fun platform for onboarding new employees	Fostering an engaging and empowering learning culture
• Need for a system to validate competence • Using skill matrices and assessment methods to evaluate and develop employee competence	Competence validation
• Language barriers affecting training and communication • Adapting training to fit local culture	Language and cultural barriers
• Lack of standardized training materials for professional maintenance • Importance of having good global training material	Need for standardized training materials

4. Results

4.1 Pre-study

The qualitative pre-study's findings provided valuable context and guided the thematic analysis presented in Table 3. This revealed the themes regarding the current training practices and perceptions toward mobile learning platforms within the company.

One of the major themes that emerged was "Fostering an engaging and empowering learning culture". Many maintenance directors expressed dissatisfaction with traditional classroom-based training, highlighting the challenges of attracting and retaining employees' attention. Additionally, they strongly preferred self-paced mobile learning solutions accessible anytime, anywhere and on diverse devices, allowing for more efficient and personalized learning experiences. This approach would balance E-learning with traditional learning (team-based on-site training). Another common theme was the "Need for standardized training materials" and "Challenges in training and development". Maintenance directors highlighted the challenges of coordinating training sessions across multiple sites and shifts and the difficulties faced by field technicians in attending on-site training.

Concerns about potential barriers to adopting mobile learning platforms, such as resistance to change and language barriers, were revealed. This emphasized the need for an easy-to-use, multi-language platform to address these concerns. Finally, maintenance directors mentioned that current face-to-face sessions foster collaborative learning, which is vital for the company's values as it enhances teamwork. Therefore, they suggested that the mobile learning platform should be a complementary or preparation tool for employees rather than a replacement for current physical workplace training sessions.

A survey was conducted in parallel using interviews with 30 white and blue-collar employees within maintenance to complement the understanding of the current state of employee training practices. The data were computed to analyze the current training experience and was performed on three key variables from the questionnaire responses: learning outcomes, education methodology in use and satisfaction level. An overview of the quantitative results of the pre-study is shown in Figure 2a.

For the learning outcomes variable, a mean of 4.4 (SD 1.9) suggests a positive acceptance regarding whether employees feel they get a high learning outcome after attending current training sessions. The educational methodology in place, with a mean rate of 4.3 indicates a

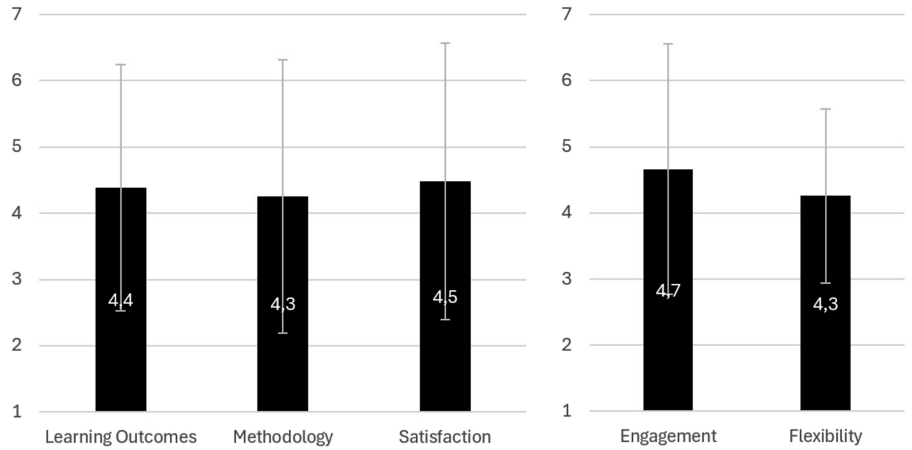

Figure 2. a) Pre-study variables results (left) and b) Inputs to design the App variables results (right)

rather positive view of it, with some variability in opinions (SD 2.1). Finally, satisfaction consequently had a mean of 4.5 (SD 2.1) regarding the current workplace training sessions.

4.2 Inputs to design the App

An overview of the quantitative results for the inputs to design the App is shown in Figure 2b. The engagement variable received the highest mean score (4.7; SD 1.9), confirming that a mobile learning platform should be highly engaging. Flexibility also scored highly (4.3; SD 1.3), indicating a common employee preference for training that impacts self-paced, modular learning compared to classical instructor-led approaches. Based on these critical user inputs and the literature review findings, a comprehensive set of features was implemented in the application. Table 4 summarizes these implemented features, clearly distinguishing their source (user-driven or literature/theory-driven) and detailing their functional implementation within the App.

Table 4. Summary of the implemented features and their sources

Feature	Source	How the feature was implemented
E-Learning (Bondar *et al*., 2020; Donath *et al*., 2020; Emerson and Berge, 2018; Emmanouilidis *et al*., 2010; Gavril *et al*., 2017; Jayanthi *et al*., 2023; Macdonald and Chiu, 2011; Papathanasiou *et al*., 2012; Papathanassiou and Emmanouilidis, 2010; Shi *et al*., 2017; Swacha and Baszuro, 2013)	Literature-driven	A digital application was developed within the company's Microsoft 365 ecosystem (PowerApps) to complement traditional instructor-led, classroom-based training using printed material
Mobile Learning (Al-Amri *et al*., 2020; Beinke *et al*., 2017; Buchem and Hamelmann, 2010; Hug *et al*., 2005; Karlsen *et al*., 2023; Macdonald and Chiu, 2011; Messuti *et al*., 2014; Ojokoh *et al*., 2013; Papathanasiou *et al*., 2012; Papathanassiou and Emmanouilidis, 2010; Pimmer and Gröhbiel, 2008)	User-Driven (Questionnaire: Flexibility)/Literature-Driven	The developed application is responsive and accessible on several gadgets such as smartphones and tablets, allowing users to start new training content from any location
Microlearning (Di Pasquale *et al*., 2024; Emerson and Berge, 2018; Nanjappa *et al*., 2023; Papathanassiou and Emmanouilidis, 2010)	User-Driven (Questionnaire: Flexibility)/Literature-Driven	Content is segmented into short micro-format modules (approx. 5–10 min), allowing sessions to be interrupted and resumed without significant loss of progress
Gamification (Beinke *et al*., 2017; Butgereit, 2016; Donath *et al*., 2020; Göschlberger and Bruck, 2017; Isik *et al*., 2024; Jooste *et al*., 2020; Kapp, 2012; Papathanassiou and Emmanouilidis, 2010; Shi *et al*., 2017; Spanellis and Pyrko, 2021; Swacha and Baszuro, 2013)	User-Driven (Questionnaire: Engagement)/Literature-Driven	Implements scores, leaderboards, motivational messages, and reminders to reinforce learning. Encourages the user to repeat steps in case of failure
Spaced Repetition (Kondratjew and Kahrens, 2019; Sinha, 2019)	Literature-driven	Learning is structured into three phases: (1) Micro-content presentation; (2) Exercises proposed; and (3) Final exam. The same content is reintroduced again when closely related to new topics

(*continued*)

Table 4. Continued

Feature	Source	How the feature was implemented
Language (Cultural) Support	User-Driven (Interviews)	Allows the user to select their preferred language on the home screen, adapting the entire software. Content translation was assisted by language experts
Competence Validation	User-Driven (Interviews)	The App content is split into 5 Levels (Beginner to Expert) and 7 Steps. Progress is visualized as a learning path
Interactivity (Real-Time Feedback) (Al-Amri *et al.*, 2020)	Literature-driven	Immediate feedback on exercises (correct/incorrect) and a bug-reporting function for flagging needed improvements
Collaboration (Christopoulos and Mystakidis, 2023; Karlsen *et al.*, 2023; Wang *et al.*, 2011)	User-Driven (Interviews: Engagement)/Literature-Driven	Allows users to recognize the progress of other users and the possibility to contact them (implicit in the leaderboard functionality)

As detailed in Table 4, the application's design was fundamentally rooted in a mixed-source approach, combining established pedagogical principles with direct organizational needs. Features such as E-learning, gamification and spaced repetition were incorporated based on academic literature, addressing known challenges related to motivation and long-term knowledge retention. Conversely, features like competence validation and language/cultural support were directly driven by user input, specifically addressing the highly-rated requirements for flexibility and the specific operational barriers identified across the multi-site organization. This structured implementation, which links features to both theoretical foundations and practical user needs, ensures the App's relevance and maximizes the potential impact on user usefulness, ease of use, ease of learning and satisfaction.

4.3 Developed App

The mobile learning application was developed using Microsoft Power Apps, a low-code platform that facilitated seamless integration with the organization's existing Microsoft 365 ecosystem. This choice enabled rapid prototyping and deployment within a familiar IT environment. The App's development followed a structured three-phase process: (1) Requirement Gathering and Design, based on pre-study findings and direct input from maintenance directors and employees; (2) Feature Implementation and Prototyping of the mobile learning platform; and (3) Testing and Refinement with actual maintenance practitioners.

The core mobile micro-learning approach was functionally implemented through a modular content structure, where each learning unit was designed as a self-contained screen within the Power App. Learning content was delivered using Power Apps' native multimedia components, including embedded video players, image galleries and interactive quiz controls (e.g. tests, checkpoints and quick tips). User content progression was meticulously tracked by recording each user's module completion status in Power Apps collections, which were then synchronized with SharePoint for persistent data storage and organizational oversight.

Gamified elements were integrated via several distinct technical implementations, as shown in Figure 3, like points system that was created using Power Apps' global

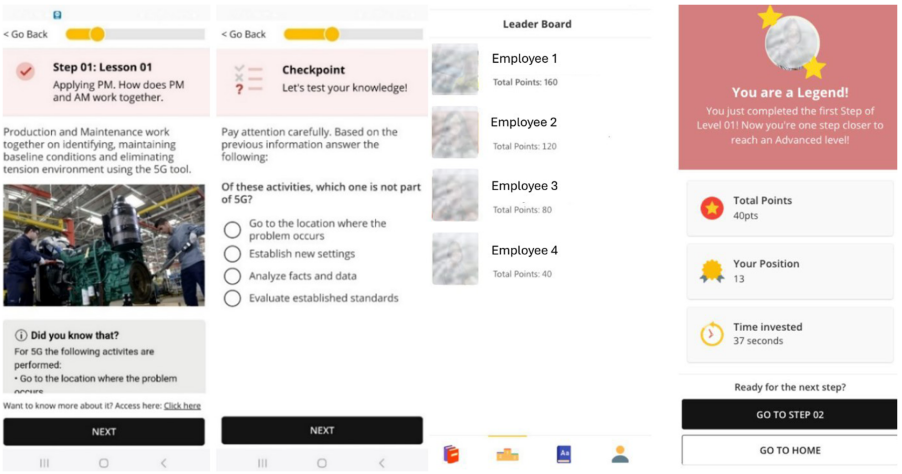

Figure 3. Engaging and interactive features implemented

variables and formulas, incrementing points based on module completion and quiz performance achievement; badges, implemented as conditional image controls that visually displayed upon the achievement of specific user progress milestones, with data stored in SharePoint; leaderboards, developed using Power Apps' gallery controls, connected to aggregated user performance data, to foster a competitive yet engaging learning environment; and progress visualization, achieved through integrated progress bar components from the Power Apps component library, providing clear visual feedback on learning paths.

To proactively address language and cultural barriers identified during the pre-study, multilingual support was implemented using conditional display logic. This allowed users to effortlessly select their preferred language directly on the home screen. Furthermore, interactivity features providing real-time feedback – such as congratulatory messages for successes and motivational prompts for incorrect answers – were integrated using dynamic conditional text displays. The App's underlying data architecture leveraged Microsoft SharePoint to securely store user profiles, learning progress and all gamification metrics, ensuring real-time synchronization across various user devices. User authentication, critical for an enterprise environment, was seamlessly handled through the organization's robust Microsoft 365 ecosystem, guaranteeing secure and authorized access for all maintenance employees.

4.4 Application feedback

Current PM instructors were recruited to evaluate the App's usability, ensuring maintenance representation from various facilities within the multi-site company. In total, 10 full-time maintenance workers aged between 28 and 45, 4 blue-collar and 6 white-collar, interacted with the App after receiving introductory training about its functionalities. Four Microsoft Teams remote training sessions were launched, lasting 35 min on average, where the participants were given a brief explanation of the study's main objectives and the App's features. Participants could navigate freely through the different screens and functionalities first, and later they were given a specific task to navigate through level 1, shown in Figure 4.

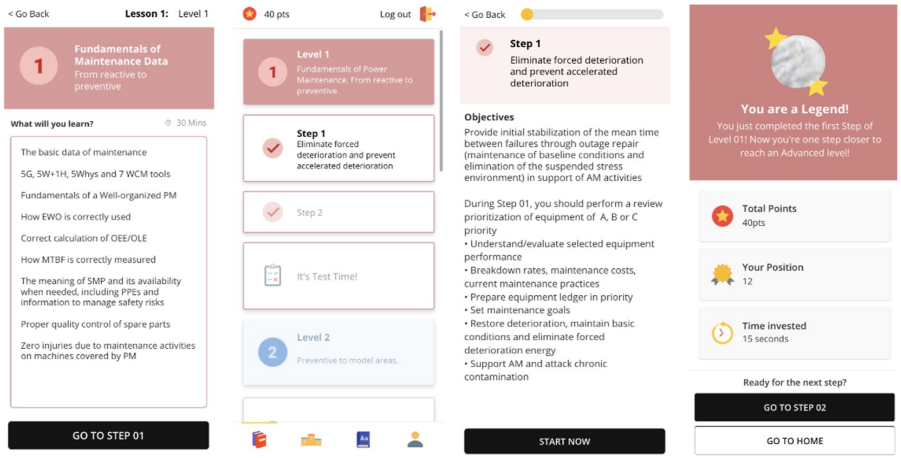

Figure 4. Step 1 within level 1

The evaluation of usability factors is crucial when implementing technology-enhanced learning tools in corporate environments, particularly in the context of mobile learning, where usability attributes such as satisfaction, efficiency, learnability, lack of errors and memorability play a significant role in promoting the adoption of a new technology-enhanced learning (TEL) platform among employees.

The USE questionnaire is initially divided into three variables, usefulness, ease of use and ease of learning, the three of them relate to the variable satisfaction. By analyzing user perceptions through a structured evaluation, companies or organizations can customize their digital learning platforms to align with the needs and expectations of their workforce, ultimately enhancing training and learning outcomes. Collected data were computed to determine the central tendency and standard deviations of perceived usefulness, ease of use, ease of learning and satisfaction among the participants. The average and most common ratings are high on the five-point Likert scale, indicating general satisfaction with the tool among study participants, as shown in Table 5.

Table 5. Overview of average ratings and variability for usability and satisfaction variables

Variable	Mean	Standard deviation
Usefulness	4.0	0.82
Ease of Use	4.4	0.75
Ease of Learning	4.5	0.58
Satisfaction	4.2	0.70

The usefulness variable retrieved a mean of 4 (SD 0.82) suggesting participants found the platform very useful. For the variable ease of use, the mean of 4.4 (SD 0.75) indicates that participants found the platform very easy to use. The ease of learning variable achieved a mean of 4.5 (SD 0.52), indicating general agreement that the platform is easy to learn. High overall satisfaction was achieved with a mean of 4.2 (SD 0.72).

Participants' open-ended feedback, gathered through the online questionnaires, provided qualitative insights. The respondents are here referred to from R1 to R8 to ensure their anonymity. These comments and suggestions offered additional perspectives on the use of the

developed application. All participants responded positively to the App developed, with comments such as "Great approach, congratulations" (R.2), "Very good App" (R.3), "Overall a user-friendly App" (R.4), "The App's navigation, design, and response speed are very good" (R.7) and "The 'Scoreboard' is also a fun way to engage people and encourage learning". Competing with coworkers for the best results would be fun" (R.7). One participant added, "Ah, I'm at the top now, it's nice to know my level" (R.1). Moreover, some participants expressed their willingness to continue using the application, asking, "Can we use it now already?" (R1), "When will it be available for everyone in the area?" (R7), and "I'll be waiting for the official launch to practice more" (R8).

However, three participants suggested improvements regarding notifications for inactivity, increased use of GIFs and videos, and answer randomization. Additionally, two participants expressed concerns about the leaderboard feature, questioning whether employees would like their scores to be visible to everyone. In terms of language preference, participants preferred to switch to their mother language when available.

5. Discussion

This study investigated the critical variables for an application to improve maintenance staff education satisfaction at a multi-site global manufacturing company, designing and validating a proof of concept including techniques such as microlearning, spaced repetition and gamification elements. It also collected maintenance instructors' feedback through an adapted version of the USE questionnaire, which evaluates the variable usefulness, ease of use and ease of learning and their relation to the variable satisfaction. Both practical and academic implications were observed, consequently impacting societal implications.

5.1 Practical implications

The thematic analysis of the interviews brought up challenges in training and development being addressed through micro-learning (Emerson and Berge, 2018), spaced repetition (Kondratjew and Kahrens, 2019) and gamification (Donath *et al*., 2020; Swacha and Baszuro, 2013) in a mobile-based (Ojokoh *et al*., 2013) platform. The second theme obtained was fostering an engaging and empowering learning culture, being addressed through interactivity and collaboration. The third theme was competence validation being addressed through micro-learning and spaced repetition. The fourth theme was language and cultural barriers being addressed via mobile applications and proper translation of the content to the selected language. Finally, the fifth theme obtained was the need for standardized training materials, targeting to replace local content with global standards, being addressed to collaboration among the sites to build a common content that matches facilities' needs.

Additionally, the pre-study questionnaire responses regarding learning outcomes from the traditional education process were addressed through micro-learning and spaced repetition. Moreover, the second obtained response regarded the methodology in use, relating to the classroom instructor-led training, being addressed through interactivity and collaboration in the use of a mobile-compatible application, fitting to the workers' lack of free-time agendas, including immediate feedback from the exercises done and the possibility to discuss the question with other users rather than relying on the instructor intervention and availability. Finally, responses obtained regarding satisfaction with the traditional educational process were addressed to the mobile compatibility adapted to microcontent followed by spaced repetition, added by the gamification approach.

The input collection to design the App was focused on the features of engagement and flexibility. For the engagement, considered by the respondents as the most important feature to be considered as input to design the App, approaches to facilitate interactivity in real-time were launched, feedbacking the user both congratulating a success or motivating when a mistake took place. Additionally, a feature to increase collaboration was added allowing the

apprentices to connect globally by discussing a question or a given answer that was not clearly understood, which can bring an administrator clarification or correction, depending on the case. Finally, the gamification feature supports this collaboration while presenting outstanding apprentices in the leaderboard screen, where top scorers are shown meaning they assimilated the content with high performance.

Regarding the second feature collected as input to design the App, flexibility, it was addressed through micro-learning with spaced repetition in a mobile-compatible platform. The possibility of performing short content assignments in a few minutes, fitting the dynamic work environment typical of maintenance workers, reverts an assumption that a formal schedule training window should be available, usually with more than one-hour duration. Secondly, revisiting this small portion of content frequently allows the apprentices to overcome the forgetting curve (Shail, 2019) barrier. Finally, apprentices' content restrictions to access the content of the training, either due to lack of access to a computer or printed material, anywhere, was addressed to the mobile-compatible feature, allowing them to use the App even with their private smartphone, making a positive contribution in terms of flexibility.

However, despite the overall positive reception, participants also provided valuable insights for further improvement, including notifications for inactive users to join back (Emerson and Berge, 2018) and increased interactivity via integrating GIFs or short videos for diversification. Such feedback emphasizes the importance of a learner-centric approach in platform design, stressing the need for just-in-time training tailored to the employee's learning path (Fox, 2016). Additionally, two participants raised concerns about the score-based elements, which may negatively expose users, aligning with previous research (Algashami *et al*., 2018; Meske *et al*., 2016) indicating that the misalignment of the integration of gamified elements in a workforce setting could create ethical concerns among employees.

5.2 Academic implications

The feedback from the developed application, conducted with maintenance employees, yielded high ratings for usefulness, ease of use, and ease of learning, reflecting high satisfaction among all participants and suggesting a perceived likelihood of continued use of the platform by the employees. As highlighted by previous research (Al-Amri *et al*., 2020; Hug *et al*., 2005), technical functionality, usability and instructional flow are crucial in designing effective and impactful mobile learning experiences, being addressed through the USE questionnaire. If users perceive the platform to be user-friendly and efficient, engagement increases, which confirms previous research indicating that designing for mobile learning in workplace settings should consider the interplay of learning, work, technology and learner agency to be efficient (Messuti *et al.*, 2014). One factor to consider is how long this innovation will remain attractive if not receive updates.

The consistently high rates for usefulness suggest the significance of technological usability, highlighting that the user experience influences the perception of value attributed to digital platforms (Mostakhdemin-Hosseini, 2009; Parsazadeh *et al*., 2018). Contrasting the satisfaction level from the pre-study (4,5 out of 7) to the developed application (4,2 out of 5) suggests that employees perceived greater satisfaction with the proposed mobile microlearning solution compared to the current traditional training approach, which supports the growing recognition in the corporate world, where sustaining long-learning sessions with engaged employees has become increasingly challenging.

This study demonstrates how gamified digital training tools can support broader organizational goals and the significant societal implications linked to workforce upskilling. By contributing to the digital transformation of industrial maintenance, the solution aligns with Industry 4.0 initiatives, Smart Maintenance in particular, promoting sustainable industrial development and competitiveness. Indirectly, fostering safer and more efficient maintenance practices positively impacts worker well-being and occupational safety, yielding both social and policy benefits.

This work has so far involved a sample size of eight experts($N = 8$) for the feedback of the developed application, which limits the robustness of the conclusions and hinders a definitive response to the research questions. Involving more respondents in further studies could present higher variables in responses, ending in a more definitive statement as to the relation of USE (usefulness, satisfaction and ease of use/learn) via a perceived continued use of the mobile learning platform.

6. Future research directions

It is suggested to further evaluate the effects of the full implementation of the application rather than only the proposed proof of concept, over an extended period that covers at least two complete cycles of the App's intended use. This approach would allow for the assessment of at least four key aspects.

The first is the recognition of knowledge retention (Shail, 2019) related to PM across the multi-site company. This connects to the second aspect, which concerns knowledge transfer among a broader group of practitioners and how to strengthen collaboration between workers from different facilities.

Building upon these two aspects, a crucial extension would involve applying established psychological frameworks to examine the long-term impact of the gamified intervention. Future studies may draw on theoretical perspectives such as self-determination theory (SDT) (Deci and Ryan, 1985) and flow theory (Csikszentmihalyi and Csikzentmihaly, 1990) to better understand how gamification supports sustained satisfaction and intrinsic motivation among maintenance employees. Exploring these psychological dimensions could provide deeper insight into how gamified elements influence continuous learning behavior and engagement in the workplace.

The third aspect refers to the ongoing administration and moderation of the App itself – maintaining its functionality, clarifying user questions, refining responses and providing feedback for improvement. Finally, the fourth aspect relates to sustaining the App's attractiveness by regularly updating both content and user experience, ensuring continued engagement and motivation to use the platform.

7. Conclusion

This study aimed to investigate the development and perception of a novel mobile learning platform for maintenance staff within a multi-site global organization, integrating microlearning, spaced repetition and gamification elements. Two research questions guided this investigation, and our findings provide clear answers.

As an answer to the first research question (RQ1), this study identified and validated a core set of features essential for enhancing maintenance staff education satisfaction. These include fundamental pedagogical approaches such as microlearning and spaced repetition, delivered through a mobile-compatible platform to ensure accessibility and flexibility in dynamic work environments. Key gamification elements (e.g. points, badges, leaderboards) were found to be crucial for driving engagement and motivation. Furthermore, features facilitating real-time interactivity, peer-to-peer collaboration and instant feedback were highly valued. These features were largely derived from an initial needs assessment, addressing challenges such as cultural/language barriers, the need for standardized materials and the desire for engaging, flexible training.

For the second research question (RQ2), the feedback from maintenance instructors, evaluated via an adapted version of the USE Questionnaire, indicated a highly positive perception of the proposed application. Consistently high ratings were observed for its usefulness, ease of use, and ease of learning, collectively reflecting a high degree of overall satisfaction among participants. This strong positive perception suggests a high perceived likelihood of continued use of the platform, positioning it as an effective and well-received complementary alternative to traditional training methods for PM education.

In practical terms, the platform effectively addressed identified gaps in corporate education, particularly the difficulty of aligning formal training with the tight schedules of maintenance workers. The integration of real-time interactivity, collaboration features and gamification elements proved to be helpful in fostering a more engaging and collaborative learning culture. However, it is important to acknowledge concerns raised regarding the ethical implications of certain score-based gamification elements, suggesting a need for careful implementation.

From an academic perspective, this study contributes significantly to the literature on corporate learning by empirically demonstrating how innovative technological approaches can be effectively tailored to the specific needs of working populations in complex industrial settings. For the host organization and other firms facing similar maintenance training challenges, the proposed platform offers substantial and immediate benefits. It provides a scalable, standardized and cost-effective solution to overcome tight scheduling conflicts and align training quality across disparate global sites. The high user satisfaction and positive perception of usefulness indicate a high likelihood of platform adoption, which is critical for ensuring sustained knowledge retention and rapid skill acquisition in critical areas like PM. By promoting self-paced learning and instant feedback, the application reduces dependency on instructor availability and accelerates the time-to-competence for maintenance staff.

In summary, this study explicitly answers our research questions, establishing a solid foundation for future investigations and improvements in the design of mobile learning platforms for corporate contexts. By effectively aligning technological usability with organizational learning needs, the proposed platform has the potential to redefine corporate education, driving enhanced employee engagement, knowledge retention and operational efficiency in a scalable and global manner.

AI usage

AI-powered language models (e.g. ChatGPT) were utilized for editing, proofreading and refining the clarity and conciseness of the manuscript's text. All generated content was reviewed, edited and approved by the authors.

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Appendix 1

Semi-structured interview questionnaire for maintenance directors

Part 1: Understanding Current Training Practices

- Can you describe the current training process for Professional Maintenance in your department?
- What are its strengths and where does it fall short?

- What are the main challenges you face with the current training system?
- Are there any specific areas where employees consistently encounter difficulties?
- What kind of feedback have you received from employees about the existing training process?
- Are there any common themes or concerns?

Part 2: Knowledge and Skills Assessment

- How do you currently assess the knowledge and skills of employees in maintenance?
- Are there distinct levels or competencies that you recognize?
- In your experience, where are the most significant knowledge or skill gaps among the maintenance staff?
- How does the current training system accommodate continuous learning and skill upgrading?

Part 3: Perception and Expectations of Gamified Learning

- How familiar are you and the maintenance team with the concept of gamified learning?
- What are your initial thoughts on using such a platform for training?
- In your opinion, what potential benefits could a gamified E-learning platform bring to maintenance training?
- Do you have any concerns or skepticism about implementing a gamified E-learning platform?
- What would these be?

Part 4: Integration and Utilization

- How do you envision integrating a gamified E-learning platform with the existing training practices?
- What strategies would you suggest to encourage engagement and regular use of the gamified platform among employees?
- How can we ensure that the gamified E-learning platform remains relevant and useful for long-term learning and professional development?

Part 5: Feedback and Improvement

- What kind of feedback mechanism would be most effective in understanding the effectiveness of the gamified platform?
- How can we continuously improve and update the platform to meet the evolving needs of maintenance training?

Part 6: Management Involvement and Employee Encouragement

- How do you see the role of management in encouraging employees to use the gamified E-learning platform?
- What specific actions can management take to motivate and support employees in this initiative?
- Are there any incentives or recognition programs that could be implemented to encourage and reward employee engagement with the gamified E-learning platform?
- How could these be aligned with existing performance metrics or professional development goals?

Additional Thoughts & Insights.

- Is there anything else you would like to add or suggest that could help in the successful implementation and adoption of a gamified E-learning platform for maintenance?

Appendix 2

Pre-study questionnaire for Maintenance Employees

General information

(1) How many years have you worked at this site?

☐ 1–3 ☐ 4–5 ☐ 6+

(2) What is your current role?

☐ Electrician and/or Mechanic

☐ Technician (Electrical and/or Mechanical)

☐ Engineer (Electrical and/or Mechanical)

☐ First-Line Manager

(3) Have you received any training about the PM methodology for your maintenance responsibilities?

☐ Yes ☐ No

Training Experience

Current PM Methodology Training Experience

(4) How satisfied are you with the quality of the current training programs? (1 = Completely Dissatisfied, 7 = Completely satisfied)

(5) What aspects of your current training do you find most beneficial?

☐ Access to resource materials

☐ Experienced instructors

☐ Relevance to job tasks

☐ Short and convenient for my work schedule

☐ Other

(6) If you selected "Other" please write here the aspects of your training you find most beneficial.

(7) Are there any specific areas of your current training that you think could be improved?

☐ More practical application

☐ Timely and constructive feedback

☐ Access to updated resources

☐ Incorporation of new technologies

☐ Other

(8) If you selected "Other" please write here the specific areas of your current training that you think could be improved.

(9) Please indicate your level of agreement with the following statements, referring to the PM Methodology. (1 = Strongly disagree, 7 = Strongly agree)

a. The training materials provided in the program are clear and understandable.

b. The training sessions I currently participate in are interactive and engaging.

c. The assessments in my current training accurately measure my understanding of the material.

d. The support and guidance provided by instructors or mentors during my training met my satisfaction.

e. My current training effectively encourages collaboration and knowledge-sharing among colleagues.

(10) Do you appreciate regular feedback on your progress during training?

☐ Yes ☐ No ☐ I feel indifferent to it

E-platforms and time management

(11) How important is the flexibility of accessing training content at your own pace? (1 = Extremely important, 7 = Extremely not important)

(12) Would you like access to learning materials that you can revisit at any time?

☐ Yes ☐ No ☐ I feel indifferent to it

(13) Are you comfortable using technology for learning such as tablets, computers, or mobile Apps?

☐ Yes ☐ No

(14) What devices do you primarily use for accessing online content (e.g. computer, tablet, smartphone)? Select all that apply.

☐ Tablet ☐ Laptop ☐ Desktop ☐ Phone

(15) Are there concerns or reservations you have about transitioning to an E-learning approach?

(16) Are there any technical challenges or limitations you believe you could have in accessing an E-learning platform?

Appendix 3

Feedback Questionnaire

General information

(1) Age

☐ 20–30 ☐ 31–40 ☐ 40+

(2) Job title

(3) Years of experience in maintenance

☐ Less than 1 ☐ 1–5 ☐ 6–10 ☐ 11+

(4) Do you have any previous experience with digital learning tools?

☐ Yes ☐ No

(5) How frequently do you use mobile applications for learning purposes?

☐ Daily ☐ Weekly ☐ Monthly ☐ Rarely ☐ Never

Usefulness

(6) Rate how useful you find the mobile application. (1 = Strongly disagree, 5 = Strongly agree)

a. It helps me be more effective.

b. It helps me be more productive.

c. It is useful.

d. It makes the things I want to accomplish easier to get done.

e. It saves me time.

f. It meets my needs.

(7) Rate how easy is the mobile application to use and learn how to use. (1 = Strongly disagree, 5 = Strongly agree)

a. It is easy to use.

b. It is user-friendly.

c. I can use it without written instructions.

d. Both occasional and regular users would like it.

e. I learned to use it quickly.

f. I quickly became skillful with it.

(8) Rate your level of satisfaction and motivation to use the mobile application. (1 = Strongly disagree, 5 = Strongly agree)

a. I am satisfied with it.

b. I feel engaged with the application when I use it.

c. It is fun to use.

d. I feel motivated to use the application for my learning.

e. I find the micro-learning* modules engaging and easy to follow *(*micro-learning modules are the different application pages with the content that you have to go through, e.g. the quizzes, the objectives, the images, etc.)*

(9) As of the time you are filling out this questionnaire, no content has been added to the modules apart from quiz questions and objectives for each level and step. Based on the information you have now and in your personal view, do you think that this mobile learning application will complement effectively the already existing instructor-led training?

☐ Yes ☐ No ☐ Maybe

(10) Please share any additional comments, suggestions, or concerns you have regarding the mobile micro-learning platform

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