

Integrating Real Work Systems into Educational Escape Games: A Human-Centred Requirements Analysis in the Context of Industrial Maintenance

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Abstract: In recent years, novel approaches to learning and education within the context of digital transformation in industrial environments have gained increasing attention. These approaches aim to foster the development of new competencies that help address barriers in change management processes, such as resistance to change, uncertainty regarding new workflows, and limited digital competencies. Escape games represent a compelling approach in this context, as they allow participants to navigate (digital) environments in a self-directed manner, interpret information independently, and make decisions under structured constraints within a safe and motivating environment. Despite the increasing adoption of such games in (educational) practice, structured requirements analyses that inform the design of didactically effective escape games remain surprisingly limited. This holds particularly true in industrial learning contexts, where transferable design principles for integrating real work systems into serious games require further empirical grounding. This paper presents the results of a requirements analysis conducted as part of a joint project between a software company and a university. The project aims to support the human-centred development of an escape game in which players solve puzzles on a digital maintenance platform in order to resolve a fictional machine failure. As part of the human-centred development process, three workshops based on an early prototype of the escape game were conducted. To ensure multi-perspective evaluation, the workshops comprised 15 participants from mechanical engineering companies as the target group, eight UX experts to refine interactions with the platform, and nine experts in simulation-based learning to evaluate the didactic foundation. A particularly critical finding concerns the role of time pressure. Although temporal constraints constitute a core mechanic of escape games, they may undermine learning objectives by prioritizing task completion over reflection and system understanding. Furthermore, the results highlighted the importance of minimizing media discontinuities, addressing data protection constraints, developing a coherent narrative with clear objectives, and focusing interactions on essential system functionalities supported by transparent feedback.

Keywords: Serious gaming, Educational escape games, Professional learning, Human-centred design

1. Introduction

Game-based learning and serious games have become increasingly relevant in professional and workplace learning (Calza-Perez et al, 2025; Pistono, Santos & Baptista, 2022). The integration of instructional content with game features such as challenges, rules, goals, control and feedback has been demonstrated to foster learner motivation and engagement (Garris, Ahlers & Driskell, 2002). In contrast to more instruction-oriented training formats, game-based learning environments allow learners to actively explore problems, test possible solutions, receive feedback and reflect on their actions in a structured and safe setting (Kiili, 2005).

Educational escape games have emerged as a particularly engaging format of serious games (Fotaris & Mastoras, 2019; Veldkamp et al, 2020). Based on the structure of escape rooms, they combine narrative-based scenarios, collaborative problem-solving, time-bound challenges and interconnected puzzles. Learners are required to independently search for information, interpret clues, test solutions and complete a shared mission within a defined scenario (Veldkamp et al, 2020). These characteristics render educational escape games especially suitable for experiential and problem-oriented learning.

This potential is of particular relevance in industrial environments undergoing digital transformation. The introduction of new digital technologies and workflows often gives rise to human-related challenges, including uncertainty about changing job requirements and work processes, resistance to change, and limited digital competencies (Han et al, 2025; Cieslak & Valor, 2025; Cyfert et al, 2025). Educational escape games have the potential to address these challenges by embedding digital tools and work-related scenarios into a safe, motivating and interactive learning environment. Learners are able to explore system functionalities, make decisions and experience feedback without being exposed to the risks associated with real operations.

Despite this potential, empirical requirements analyses of educational escape games within human-centred design processes remain limited. Existing work on educational escape games has primarily emerged from general educational settings and from domains such as healthcare (Veldkamp et al, 2020; Quek et al, 2024). At the same time, broader serious-games research has addressed professional training and industrial transformation more generally (Brauner & Ziefle, 2022; Pistono et al, 2022). However, educational escape games for industrial learning settings appear to remain comparatively underexplored. This holds particularly true for applications that integrate real work systems, such as existing digital platforms.

This paper addresses this gap by presenting an exploratory, multi-perspective requirements analysis for the human-centred design of educational escape games in industrial learning contexts. The study is based on an early prototype developed as part of a joint project between a software company and a university, which integrates an existing digital maintenance platform into a fictional machine-failure scenario. Based on three workshops with professionals from mechanical engineering companies as the intended target group, UX experts, and experts in simulation- and game-based learning, the study derives design requirements for educational escape games that integrate real work systems into industrial learning scenarios. The contribution of this paper lies in identifying design requirements for educational escape games that integrate real digital work systems, showing that authenticity and didactic alignment involve concrete trade-offs in industrial learning scenarios.

2. Theoretical Background

2.1 Serious Gaming and Game-based Learning

Game-based learning is commonly understood as gameplay with defined learning outcomes (Plass, Homer & Kinzer, 2015). Serious games are similarly described as games that are not primarily designed for entertainment, but pursue an explicit educational, training-related or other serious purpose (Abt, 1970; Laamarti, Eid & El Saddik, 2014). The two concepts are not clearly distinguished in the literature and are closely related to each other (Fromme, Biermann & Unger, 2010). Across these concepts, the central idea is to combine instructional content with game features such as goals, rules, challenges, feedback and interaction in order to create active, engaging, and safe learning environments (Garris, Ahlers & Driskell, 2002; Kiili, 2005; Plass, Homer & Kinzer, 2015).

Consequently, game-based approaches have the potential to facilitate the connection between knowledge acquisition and active application, experimentation, feedback, and motivational engagement (Connolly et al., 2012). By enabling learners to engage with complex problems, make decisions and experience consequences in structured environments, they offer opportunities to practice without the risks and costs of real operations (Brauner & Ziefle, 2022; Lateef, 2010). Empirical evidence supports this potential, indicating positive effects of game-based training approaches on self-efficacy, declarative knowledge, procedural knowledge and retention (Sitzmann, 2011). Taken together, these characteristics position game-based approaches as a promising foundation for designing learning environments in professional and industrial learning contexts.

2.2 Educational Escape Games

Educational escape games are learning-oriented adaptations of recreational escape rooms, in which teams complete a time-bound mission by collaboratively searching for information, interpreting clues and solving interconnected puzzles (Nicholson, 2016; Veldkamp et al., 2020). With the growing popularity of this format, educators and trainers began to use escape-game scenarios as collaborative, problem-oriented settings for engaging learners with educational content (Sanchez & Plumettaz-Sieber, 2019). Educational escape games have been applied in different educational and professional domains, such as healthcare, higher education and cybersecurity training (Guckian, Eveson & May, 2020, Scandurra & Ciofi, 2023, Spatafora et al, 2024). In industrial contexts, however, they appear to be less established, although digital transformation creates a growing need for learning formats that support employees in dealing with new technologies, changing workflows, and limited digital competencies (Cieslak & Valor, 2025; Szabó et al, 2023; Vial, 2019). This points to an underexplored potential for educational escape games in industrial learning contexts, particularly as they may make abstract technological and organizational changes more tangible through experience-based learning.

However, this potential depends on how central escape-game mechanics are designed and aligned with the intended learning objectives. Core design elements of educational escape games include narrative and mission design, puzzle-based task progression, challenge and time pressure, feedback, and media-based interaction (Nicholson, 2016; Veldkamp et al., 2020; Fotaris & Mastoras, 2022). These elements are not inherently beneficial for learning. While they may increase engagement, additional game elements can also distract learners from essential content if they are not carefully integrated with the instructional goal (Ninaus et al, 2023). This

underlines the need to align escape-game mechanics with pedagogical goals, especially when real work processes and digital systems are part of the learning environment (Veldkamp et al, 2020). Consequently, educational escape games for industrial learning contexts need to be adapted to the specific users, tasks, learning objectives, and contexts of use. A human-centred design process, including an early requirements analysis, can support the alignment of game mechanics and didactic goals (DIN EN ISO 9241-210, 2020).

3. Method

3.1 Study Design

This study employed a formative qualitative research design to derive design requirements for a digital escape game in an industrial learning context. Due to limited design guidance for integrating work-related digital systems into escape-game-based learning formats, a multi-stakeholder workshop approach was selected to examine domain fit, user experience, and didactic suitability. This is consistent with human-centred design, which emphasizes an explicit understanding of users, tasks, and contexts of use as well as iterative evaluation and refinement (DIN EN ISO 9241-210, 2020). The overall study comprised three workshops: Workshop 1 (W1) involved representatives of the intended target group from mechanical engineering companies, Workshop 2 (W2) involved UX experts, and Workshop 3 (W3) involved experts in game-based and simulation-based learning.

3.2 Prototype and Study Context

The evaluated artefact was an early prototype of a digital educational escape game situated in the context of industrial maintenance and digital service processes. The game was built around a fictional machine-failure scenario in which participants had to collaboratively support a fictional technician in resolving the incident. To do so, participants had to solve a sequence of interconnected puzzles, each yielding one numerical machine-related parameter. In total, six parameter values had to be identified and entered correctly using six separate sliders to restore the machine. The puzzles were deliberately designed to be accessible and did not require specialised prior knowledge of machinery. Rather, they served to familiarise players with the digital maintenance platform, the media used throughout the game, and the workflow of remotely supporting a technician via structured platform-based processes. The prototype followed a hybrid format: analogue clue cards provided hints, directed players to different tasks, and prompted the use of various media, while the actual puzzle solutions were entered and processed via a digital maintenance platform. The game combined puzzle solving with several digital media and communication channels, including the browser-based maintenance platform, telephony, video, e-mail, calendar-based elements, and SMS notifications sent to participants' smartphones during gameplay. The intended learning objectives were to familiarize participants with the basic workflow of digital maintenance support, to promote orientation within the maintenance platform, and to support collaborative problem-solving in digitally mediated service processes.

3.3 Participants

In W1, 15 participants from mechanical engineering companies represented the intended target group; in W2, eight UX experts contributed a user experience perspective; and in W3, nine experts in simulation games and game-based methods contributed a didactic perspective. The 15 target-group participants had professional backgrounds in maintenance-related and adjacent industrial functions within mechanical engineering and worked in four small groups. The eight UX experts and nine simulation/game-based learning experts worked in three small groups each.

3.4 Procedure

At the beginning of each workshop, participants received a brief introduction to the scenario and the overall game logic. They were informed that their task was to remotely support a fictional technician on site in resolving a machine failure and that analogue clue cards would provide hints for puzzle solving and guide the use of different media and the digital maintenance platform. In each workshop, participants played the prototype and reflected on their experience from the perspective most relevant to their expertise. While W1 and W3 used a structured debriefing format, W2 focused on an exploratory expert review of user experience. The use of debriefing in W1 and W3 was intended to support structured post-game reflection, which is widely regarded as an important element in learning-oriented simulation and game-based settings (Lee et al., 2024; Tan et al., 2024).

W1 and W3: Target-group and didactic perspective

In both workshops, participants played the escape game in small groups and were observed throughout the gameplay phase. After gameplay, a structured debriefing was conducted. The debriefing questions addressed team collaboration, perceived learning about digital processes and teamwork, encountered difficulties, and ideas for extending the game with additional work-related tasks or topics.

The workshops differed in analytical focus: W1 emphasized domain relevance, comprehensibility, practical applicability, and industrial use cases. W3 focused more strongly on the game's didactic and learning-related qualities. Here, the discussion particularly addressed how the prototype should be designed and facilitated in order to better support learning processes, reflection, and team dynamics. Responses were collected on a poster and jointly discussed as part of the debriefing.

W2: Usability and UX perspective

In W2 eight UX experts interacted with the prototype in three small groups and assessed it by actively playing and probing the game. In contrast to W1 and W3, the emphasis was less on practical or didactic embedding and more on identifying interaction problems, weaknesses in navigation and information flow, and broader UX-related issues. At the same time, game-related aspects were not excluded and were discussed where relevant to the user experience. Methodologically, the workshop followed a pragmatic expert review with walkthrough-like elements. Participants explored the prototype, identified UX issues, and consolidated them in a moderated feedback session.

1.5 Data Collection and Analysis

The workshops were not audio-recorded. The available material differed by workshop. For W1 and W3, it comprised documented moderator notes including gameplay observations and paraphrased discussion protocols, and poster-based responses generated during the structured debriefing. For W2, it comprised documented observations, UX issues, and moderator notes from the moderated feedback session. The material was analysed using a theory-guided qualitative content analysis based on Mayring and Fenzl (2019). Five requirement categories were defined deductively prior to categorisation based on the study's theoretical framing and the literature-informed design dimensions relevant to educational escape games and game-based learning: Narrative and Mission Design; Puzzle and Task Design; Challenge, Time and Competition; Feedback and Progression; and Media and Interaction (Nicholson, 2016; Veldkamp et al., 2020; Fotaris & Mastoras, 2022).

These categories served as the analytical framework for structuring the material. Two researchers first reviewed the material from W1, W2, and W3 separately and assigned all documented observations, comments, and written outputs to the respective deductive categories in a consensus-oriented qualitative procedure. The workshop affiliation of each observation or comment was retained throughout the analysis to preserve the target-group perspective of W1, the UX perspective of W2, and the didactic perspective of W3. In a subsequent step, the categorised material was compared across workshops to identify both convergent requirements and requirements specific to individual stakeholder perspectives. Discrepancies and interpretive uncertainties were discussed until agreement was reached.

4. Results

Overall, participants perceived educational escape games as a promising approach for supporting learning in industrial contexts. Across the workshops, the general idea of embedding a digital maintenance platform into a game-based scenario was regarded positively, and several participants indicated that they could imagine using such a format in practice. At the same time, the feedback pointed to several design requirements for further development. These requirements are structured along five categories and are summarized in Table 1.

Table 1: Categories and derived requirements by stakeholder perspectives (W1 = target group, W2 = UX experts, W3 = experts in simulation- and game-based learning)

Category	Derived Requirements
Narrative and Mission Design	Coherent narrative frame (W2, W3) Clear and realistic mission and game objective (W1, W3) Common thread throughout the scenario (W1) Clearly defined fictional roles and support characters (W3)

Category	Derived Requirements
Puzzle and Task Design	Alignment of puzzles with learning objectives (W3) Purposeful information search and problem-solving (W2, W3) Reduction of irrelevant or misleading platform areas (W2, W3) Input formats that prevent trial and error guessing (W2, W3)
Challenge, Time and Competition	Cautious use of time pressure (W1, W2, W3) Challenge through meaningful problem-solving rather than stress (W2, W3) Priority on exploration and understanding (W3) Cooperation over speed-based competition (W1, W3) Avoidance of mechanics that encourage unsystematic interaction (W2, W3)
Feedback and Progression	Immediate feedback on user actions (W3) Visible confirmation of completed tasks (W3) Transparent scenario progress (W3) Clear indication of completed steps (W3)
Media and Interaction	Minimal media disruptions and channel switching (W2, W3) Limited number of interaction channels (W2, W3) Privacy-sensitive handling of communication and data (W3)

1.1 Narrative and Mission Design

Across all three workshops, participants emphasized that the game requires a coherent narrative frame and a clearly communicated mission. The UX experts (W2) questioned the plausibility of the premise, noting that it remained unclear why the fictional technician was confined to the machine room by a machine failure alone, which caused confusion rather than immersion. Target-group participants (W1) considered the premise insufficiently application-oriented, noting on a poster that "the 'right' fault was missing" and suggesting a malfunction reported by a customer on a real machine as a more credible starting point. They further wrote that the story needed "a common thread". The didactic experts (W3) further called for supporting characters and their roles to be explained explicitly and for the objective to be stated clearly at the outset.

4.1 Puzzle and Task Design

During the didactic workshop (W3), groups were observed entering the six parameter values by trial and error instead of deriving them from the information found on the platform, as the input mask permitted an unlimited number of attempts. The UX experts (W2) noted the same weakness in the discussion. Both groups (W2, W3) further reported that areas of the platform that were irrelevant to the game remained accessible and misled players, and recommended hiding them where they do not contribute to the solution. The UX experts (W2) additionally characterized the way participants navigated the platform as "aimless clicking" without a clear search strategy. The didactic experts (W3) pointed out that the tasks primarily required searching the platform for parameter values. Players therefore had to use its functions, but engaged with them only instrumentally rather than developing an understanding of the workflows they represent.

4.2 Challenge, Time and Competition

Across all three workshops, time pressure was identified as the mechanic least compatible with the intended learning process. A target-group participant (W1) wrote on a poster that "time pressure impairs" the intended engagement with the platform. The UX experts (W2) proposed replacing explicit time pressure with a factual framing, namely the objective of keeping machine downtime as low as possible. The didactic experts (W3) argued that the combination of a leaderboard and a time component produces competitive behavior, leading participants to move through the platform quickly and unsystematically. This was reflected in the gameplay observations: in both W1 and W3, groups working in close proximity verbally announced that they would be faster than the others. While this motivated participants, it also led to less structured task processing, with teams focusing on speed rather than on the structure and functions of the platform.

4.3 Feedback and Progression

Feedback and progression were addressed exclusively by the didactic experts (W3). They emphasized that completed tasks require visible confirmation and suggested a simple indicator, such as a green light, signalling that a target parameter had been set correctly. During gameplay, groups were observed to be occasionally uncertain which of the six parameters a value they had found belonged to. As the configuration could only be verified once all parameters had been entered, and no information was given about which of them was incorrect, no indication of progress was available until the very end of the scenario.

4.4 Media and Interaction

In addition to working on the maintenance platform, participants had to check e-mails, telephone messages, SMS and calendar entries and to use analogue clue cards. The didactic experts (W3) identified these media disruptions as the central obstacle, and groups were observed to be visibly overwhelmed by the number of parallel channels. The UX experts (W2) reported that the volume of messages distributed across different channels made it difficult to maintain an overview of the scenario and the current tasks. The didactic experts (W3) further raised data protection concerns regarding the use of participants' own e-mail addresses and the platform-internal video chat.

5. Discussion

This study derived design requirements for an educational escape game in an industrial learning context. The findings confirm that game elements do not automatically support learning (Ninaus et al., 2023; Veldkamp et al., 2020). More specifically, they point to a recurring pattern in which properties that contribute to the authenticity of a real work system can be the same ones that impede learning in a game format, while mechanics constitutive of the escape-game format may direct attention away from engagement with that system.

This pattern was most apparent in relation to time pressure and competition. Although both elements are characteristic of escape games, they were identified across all three workshops as the mechanics least compatible with the intended learning objective. Rather than intensifying engagement with the platform, they redirected attention away from it, as teams moved through the system at speed instead of understanding its functionality and structure. Notably, the UX experts did not propose removing temporal framing altogether, but suggested replacing the countdown with an operationally meaningful objective.

A comparable tension applies to the remaining requirements. Media disruptions cannot be regarded solely as a design flaw in this context, since switching between the platform, e-mail, telephone and analogue documents reflects the conditions of industrial maintenance work, which the prototype reproduced deliberately. The results nevertheless indicate that realistic channel diversity exceeded both what learners were able to manage and what was conducive to the learning process. Feedback constitutes a comparable case. Immediate confirmation is a standard principle of game design, whereas real work processes frequently provide no direct response to an individual action. Puzzle design points in a similar direction, as the tasks turned the platform into a search space in which players operated its functions without developing an understanding of them. Guidance is consequently required, yet excessive guidance reduces the exploratory character that distinguishes escape games from conventional training formats. The same applies to narrative, which benefits from a coherent storyline with clearly stated objectives, a form of linearity that everyday maintenance work rarely exhibits.

Taken together, these observations suggest that educational escape games integrating real work systems cannot resolve the tension between operational authenticity and game design by maximizing either dimension, since both can work against the learning process. Design decisions instead require a deliberate selection of which aspects of operational reality are reproduced and which are simplified for the purpose of learning. The multi-stakeholder approach proved useful in identifying these trade-offs, as the didactic perspective raised feedback requirements that were not articulated by the other groups, while the UX perspective identified structural obstacles within the platform itself.

The study is limited by its formative design, the early prototype stage and the focus on one specific industrial maintenance context. The analysis relied on documented workshop outcomes, observations and written outputs rather than on fully transcribed data, which constrains analytical depth. Transferability to other industrial domains and escape-game designs therefore remains limited and should be examined in future research. The results should be understood as design-oriented requirements rather than as evidence of learning effectiveness. Future work should evaluate later prototype versions more systematically, including learning outcomes,

usability, motivation and self-efficacy, and should examine how challenge mechanics derived from the work context affect both engagement and system understanding.

In conclusion, educational escape games appear promising for industrial learning when they render digital work systems tangible through experience-based learning. Their didactic value, however, depends on a deliberate decision as to where operational authenticity is reproduced and where it has to give way to the requirements of learning.

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