

Innovative Approach: Leveraging Design Thinking for Enhancing Knowledge Sharing in Knowledge Intensive Firms

Hamid Roham, Elham Kamouri Yousefabad, Sepideh Aghajani, Mohammadreza Shahbazirad and Mohammad Ali Avestam

Mapna Turbine Blade Engineering and Manufacturing CO.

hamid.roham@outlook.com

elham.kamoori@gmail.com

s.aghajani86@gmail.com

shahbazi.reza@live.com

avestam@gmail.com

Abstract: Purpose: This research delves into the intricate challenges of knowledge management (KM) within technical departments of knowledge-intensive firms (KIFs), with a specific focus on preserving critical knowledge amidst employee turnover. Recognizing the four main components of KM—people, process, content/IT, and strategy—and emphasizing the paramount importance of individuals in KM alongside the human-centric approach of design thinking (DT), the study aims to enhance KM processes, particularly knowledge sharing (KS), utilizing DT to fortify organizational success. **Methodology:** This study utilizes mixed method action research, which includes in-depth interviews and observations, immersion and questionnaire to collect employee insights. Thematic analysis is utilized to identify key challenges. Employing the DT framework, the research progresses through problem definition, ideation, prototyping, testing, and iterative refinement stages, following the structured steps of DT. **Findings:** Thematic analysis identifies persistent KM challenges, encompassing individual, organizational, and technology barriers. These challenges are effectively addressed through innovative solutions developed with DT principles, leading to tangible enhancements in KM processes. Iterative cycles of prototyping and testing further refine these solutions, particularly in facilitating KS among employees. **Originality:** This research demonstrates the efficacy of DT in addressing KM challenges within KIFs. Through prioritizing human-centric problem-solving, DT's iterative and learning-oriented nature boosts organizational efficiency and stimulates innovation. The direct engagement of end-users in solution design further highlights the cost-effectiveness of this approach, ultimately enhancing KM outcomes. **Contribution:** The study presents solutions tailored to the unique challenges of KM, transferable not only within the technical department but also across KIFs. Given the prevalence of unsuccessful KM implementations, the human-centric ethos of DT emerges as a pragmatic and economical approach for diagnosing and mitigating KM obstacles. Nonetheless, the study highlights the adaptability of DT in addressing specific KM issues, offering a pathway for other departments to tackle their KM challenges effectively.

Keywords: Knowledge Management, Knowledge Sharing, Knowledge Intensive Firms, Design Thinking, Innovative Solutions.

1. Introduction

KM has become a crucial factor in ensuring organizational success and the continuity of their operations (Xue, 2017). KM encompasses the processes of creating, generating, capturing, storing, sharing, and utilizing knowledge to enhance individual performance (Ismail & Yusof, 2010). KS has been recognized as the key process for enabling organizational learning and innovation, which is particularly essential. It is crucial for organizations aiming to leverage their knowledge as an asset to gain a competitive advantage, such as KIFs. These firms depend heavily on knowledge and expertise to function, innovate, and compete in their markets. They prioritize knowledge creation, acquisition, transfer, and application to support their business goals and secure a competitive edge.

Maintenance departments play a crucial role in ensuring optimal equipment performance and sustainability. The knowledge of maintenance employees is invaluable for identifying problems, preventing breakdowns, and enhancing performance. With rapid technological advancements, KM in maintenance is becoming increasingly important.

Problem-solving skills are recognized as essential for innovative organizations in the 21st century. These skills enable organizations to overcome challenges, seize opportunities, and maintain a competitive edge. DT, a non-linear, collaborative, and iterative process, is a problem-solving approach that addresses complex problems and creates new human-centered solutions (Boersma, 2017). DT combines what is desirable from a user perspective with what is technically feasible and economically viable to generate innovative ideas. The values that DT can provide include innovative solutions, customer orientation and integration, asking the right questions, divergent thinking, tangible results, an agile approach, and risk reduction. As people are the most critical element in KM and the DT process is a human-centered approach specifically for solving complex problems, this study aims to

revisit the challenge of improving KM through the lens of DT. The integration of KM and DT became the central theme of this research.

Given the risk of knowledge loss, revisiting the topic of KM in the maintenance department has been prioritized. Prior to this research, although some steps had been taken towards KM in the maintenance department, the results were not tangible, and voluntary KS was not a common practice (Roham et al.). In other words, despite the high value placed on knowledge within the organization, KS was not an ingrained value. The investigation into the practical challenges encountered by knowledge users in maintenance departments of KIFs revealed insights into the enablers and barriers to KM and KS. The results highlighted various factors influencing efficient KM and KS, including the lack of a standardized language for recording experiences, the fear of sharing unsuccessful outcomes, and the reluctance of technical personnel to document reports (Roham et al.). Their findings indicate that KS is uncommon in maintenance departments. In these departments, individuals are often rewarded for their knowledge rather than their willingness to share it, presenting a complex problem. This study explores KM challenges in maintenance department of a KIF, particularly in preserving critical knowledge during employee turnover. This study demonstrates that by integrating DT and engaging employees throughout the process, along with utilizing iterative refinement, it aims to enhance KS with a focus on human-centric solutions. This approach is especially effective in preserving critical knowledge during employee turnover.

2. Literature Review

2.1 The Role of People and Communication in KM and KS

KM fundamentally revolves around people—how they develop, exchange, and utilize information. Therefore, KM programs should address both the gathering and communication aspects. The gathering aspect focuses on connecting individuals to knowledge, involving the capture and dissemination of specific information. Conversely, the communication aspect emphasizes connecting individuals with other knowledgeable people, thereby enhancing the flow of tacit knowledge through improved human interaction and communication processes (Mostofa et al., 2020). The success of KM initiatives hinges on effective KS (Wang & Noe, 2010). Even the most advanced technology will be ineffective if individuals are unwilling to share their knowledge (Zheng, 2017).

2.2 Unveiling DT: Unleashing Creativity

DT is a specialized approach used to address complex challenges and to cultivate innovative solutions through a human-centered approach involving multidisciplinary teams. It is termed "human-centered" because it places the needs and interests of people at the core of its strategy (Mostofa et al., 2020). It is commonly referred to as an iterative problem-solving and innovation process within organizations. This approach is rooted in specific principles, such as prioritizing user needs and embracing multidisciplinary, while employing distinct methods like creative thinking, visualization, and experimentation (Rösch et al., 2023). In this research, the double diamond process model, developed by the UK Design Council in 2005 was used in the DT process. This model is represented by a simple diagram illustrating the divergent and convergent stages of the design process, giving it the distinctive shape of a double diamond (Tschimmel, 2012). The model is also known as the 4D model because each phase begins with the letter 'D': Discover, Define, Develop, and Deliver. Figure 1, presents this model.

DESIGN THINKING PROCESS

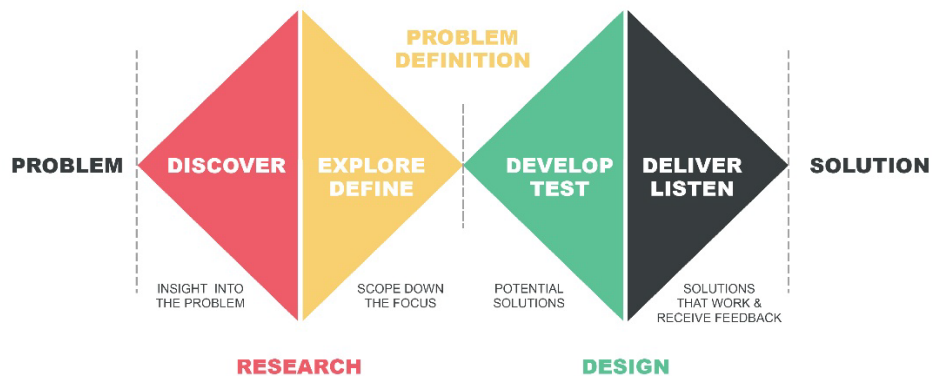


Figure 1: Double diamond model (based on UK Design Council).

DT stages have been defined as follows (Tschimmel, 2012):

1. Discover: The first quarter of the Double Diamond represents the project's initial divergent phase, where the designer explores new opportunities, gathers information, identifies trends, and uncovers insights. This stage involves developing empathy maps and personas to deeply understand the employees' needs, frustrations, and motivations.
2. Define: The second quarter, which concludes the first Diamond, is the Definition stage. Here, initial insights are reviewed, selected, or discarded, serving as a filter for refining ideas. This stage synthesizes the findings from the empathy phase into a clear problem statement.
3. Develop: In this stage, multidisciplinary teams use DT tools such as brainstorming, sketches, scenarios, renderings, and prototypes to develop, iterate, and test solutions within the company. Creative techniques encourage innovative thinking. Prototypes are iteratively refined based on feedback from the testing phase, involving multiple cycles of prototyping and testing until the solutions are optimized to meet employees' needs effectively.
4. Deliver: In the final phase, the convergent Deliver stage, the final concept undergoes final testing, is approved, produced, and launched.

2.3 Applying DT to KM

The trend of KS fostering innovation extends to design consultancies, where the fast-paced environment pressures designers to produce innovative solutions rapidly (Wu, 2020). Many believe that KM is struggling to survive, but the emergence of human-centered DT offers a revitalizing solution (Boersma, 2017). By incorporating the core elements of DT—Experimentation, Collaboration, Human-centeredness, and Optimism (ECHO)—KM can flourish. This powerful combination maximizes the value of knowledge in ways that truly connect with individuals. It enables KM practitioners to develop solutions that better resonate with the people they serve (Boersma, 2017). The future of KM has been apparent for quite some time: it lies in DT and may well be recognized as Knowledge DT (Boersma, 2017). Some KM systems already embody this human-centered philosophy (Mostofa et al., 2020). By incorporating essential knowledge into every phase of the DT process, organizations can develop innovative solutions that adjust to changing customer needs and provide more effective results (Numprasertchai & Numprasertchai, 2024).

2.4 Research Gaps, Research Objectives and Research Questions

2.4.1 Research Gaps

Exploring the literature reveals that employing DT for addressing KM and KS challenges is a relatively novel approach. The research delves into the intricate challenges of KM within technical departments of KIFs, Traditional methods have dominated the strategies used to tackle KM issues, with minimal exploration into the integration of DT. This study highlights the paramount importance of individuals in KM, aligning with the human-

centric approach of DT. The research demonstrates the efficacy of DT in enhancing KM, presenting a significant gap and potential for further innovative research in this underexplored area.

2.4.2 Research Objectives

Facilitating KS in the maintenance departments has always been one of the challenges for KIFs and several initiatives have been undertaken in this regard. The objective of this research is to enhance KS within the maintenance department of KIFs.

2.4.3 Research Question

How can DT principles be effectively applied to overcome KM challenges, specifically in KS, within the technical departments of KIFs amidst high employee turnover?

3. Method

3.1 Research Design

This study employs mixed method action research to explore and address the challenges of KM and KS within maintenance department of a KIFs, with a particular focus on preserving critical knowledge amidst employee turnover. Action research is chosen for its iterative, participatory nature, which aligns well with the objectives of engaging researchers and employees in the process of identifying problems and developing practical solutions. Additionally, DT is integrated into the action research method to leverage its human-centric and innovative approach to problem-solving. Action research in this study follows a cyclical process of planning, acting, observing, and reflecting, which is conducted collaboratively with participants from a maintenance department. This methodology is particularly suitable for addressing real-world problems in a dynamic environment, allowing for continuous feedback and refinement of solutions. DT is incorporated into the action research process to enhance the development of KM solutions. The DT framework involves four key stages: discover, define, develop and deliver. These stages are embedded within the action research cycles to ensure a thorough understanding of user needs and iterative improvement of solutions.

3.2 Questionnaire Design

The research questionnaire was designed with three objectives: (1) identify problems employees face in KS, (2) evaluate changes in knowledge levels pre- and post-prototype implementation, and (3) measure improvements in KS due to the proposed idea. The construction of the questionnaire was guided by prominent references, including Fullwood (2014), Karamitri et al. (2020), Oyemomi (2017), Wu (2020), and Welschen (2014). Leveraging the expertise and findings from above mentioned sources, the questionnaire was crafted and then refined through multiple feedback rounds by three experts in KM and DT, enhancing its validity and relevance to the research objectives. To quantify attitudes and opinions, a 7-point Likert scale was employed for the closed-ended questions.

Data Collection: This study was conducted in a KIF with 1,250 employees, including 108 maintenance personnel. Out of these, 25 maintenance employees were selected for interviews and to answer the questionnaire, alongside 5 stakeholders and KM experts.

Data collection used four primary tools:

1. **In-depth Interviews:** Semi-structured interviews with stakeholders to gather insights into their experiences and perceptions of KM and KS.
2. **Observations:** Direct observation of daily operations and KM practices to identify unspoken challenges and behaviors.
3. **Immersion:** Researchers immersed themselves in the work environment to uncover informal practices and subtle dynamics.
4. **Questionnaire:** Distributed to collect quantitative data on KS behaviors and assess the effectiveness of KM strategies.

3.2.1 Data Analysis

A thematic analysis is conducted on the collected data to identify recurring themes and patterns related to KM challenges. This involves coding the data and categorizing it into key themes. The findings from the thematic analysis guide the subsequent stages of the DT process.

3.2.2 Validation and Reliability

Multiple data sources (In-depth interviews and observations, immersion and questionnaire) are triangulated to ensure the validity and reliability of the findings. Additionally, participant feedback is continuously sought during the DT stages to validate the relevance and practicality of the proposed solutions.

3.2.3 Biases

Biases in research can lead to misleading conclusions, but efforts were made to minimize them. Collecting data from a single company introduces potential bias, so diverse participants from various power-interest levels were included. To reduce interpretation bias, targeted questions evaluated proposed solutions, and stakeholder interview responses were mapped onto empathy maps (Thinks, Says, Feels, Actions).

4. Results

In this section, the results obtained from combining action research and DT have been presented according to DT stages. Initially, the primary problem statement in the DT process was defined as follows: How can the process of recording and retrieving experiences and lessons learned by maintenance personnel of key equipment and machinery be transformed to be user-friendly and efficient? The goal is to reduce equipment downtime, minimize redundant work and associated costs, and mitigate the risk of losing valuable knowledge from experienced individuals in key areas. This problem statement was defined with the following objectives:

- Enhance the user-friendliness and efficiency of the system for recording and retrieving experiences and lessons learned.
- Reduce equipment downtime.
- Minimize redundant work and associated costs.
- Lower the risk of losing valuable accumulated knowledge when experienced personnel leave the organization.

A crucial aspect of the DT process is empathy. At the beginning of the DT process, it is essential to accurately identify user needs, where empathy plays a key role. Empathy is crucial to correctly define user needs, as these often differ from what users explicitly state. Proper empathy can uncover these actual needs.

4.1 Discover

In the first stage of the double diamond model, stakeholders were analyzed based on their power and interest regarding KM and their influence on the subject. The main stakeholders were then identified. Thirty in-depth interviews were conducted with these stakeholders. The results led to identifying of the primary user needs and a refined problem definition.

The revised problem statement is as follows:

How can the process of recording and retrieving experiences and lessons learned in the maintenance and repair of key equipment and machinery be transformed to enhance human interactions, facilitate network communications, and be user-friendly and efficient? This transformation should mitigate the risk associated with losing key knowledge and, over time, decrease equipment downtime, rework, and associated costs.

This problem statement was defined with the following objectives:

- Long-term improvement: Enhance methods for recording and retrieving experiences in the maintenance unit to reduce equipment downtime and associated costs.
- Enhanced interactions: Improve human interactions and facilitate communication to boost the effectiveness of KS.
- Quality reporting: Increase the number of high-quality reports on equipment failures, including detailed work descriptions, technical data, lessons learned, and ineffective methods.
- Frequent referencing: Encourage frequent referencing of the recorded histories of key machinery.

The results indicated that maximizing participation in the designed KM process requires creating conditions that enhance human interactions and network communications.

In the first stage of the double diamond model (Discover), two categories of information were collected: primary information from in-depth interviews, observation, and immersion, and secondary information from studying various sources, benchmarking three successful organizations and interviewing experts.

This research involved a comprehensive review of KM literature, benchmarking of three successful companies, and interviews with several experts. Key insights include:

- Rewarding collective performance: A common barrier to improving KS is the tendency of companies to reward individual performance, which promotes the notion of "knowledge is power" and contradicts a KS culture. Rewarding collective performance can mitigate this issue.
- Granting ownership rights: Acknowledging and granting ownership rights to knowledge creators fosters a sense of value and responsibility.
- Building trust and commitment: Establishing trust and commitment in communications is crucial for effective KS.
- Real-time reporting: Emphasizing the importance of recording reports in real-time ensures accuracy and timeliness.
- Sharing failure experiences: Normalizing the sharing of failure experiences can provide valuable learning opportunities and prevent repeated mistakes.
- Contextual best practices: Recognizing that best practices from other organizations may not be suitable for your organization highlights the need for tailored solutions.
- People Over Processes: Prioritizing people over processes, infrastructure, and other elements is essential for the effectiveness of this project.

These insights underscore the importance of a supportive culture and strategic practices in enhancing KM.

4.2 Define

In the second phase, insights gathered from in-depth interviews, observations, immersion techniques, articles, books, expert interviews, and company benchmarks were thoroughly reviewed and analyzed. Given the high volume of insights, to converge the results, they were categorized into four groups: People, Process, IT/Content, and Strategy. Classifying all insights into these four categories not only helped converge the information but also assisted in identifying more suitable solutions for existing problems. Additionally, insights that were frequently mentioned were given higher priority. Table 1 summarizes the most frequently mentioned insights.

Table 1: Summary of key insights from primary and secondary sources

Category	Insight
People	<ul style="list-style-type: none"> • Maintenance operation and planning conflict resolution • Collaboration • Enhancement of communication between maintenance employees and operators of equipment • Importance of recognition methods • Employee engagement • Importance of face-to-face training • Lack of time • Considering generation gap in KS • Retention and promotion of experienced employees • Variety of motivational methods • Considering individuals' interests in training • Building trust among employees • Normalization of discussing failure experiences • Developing a customized KM process • Attention to diverse learning styles
Process	<ul style="list-style-type: none"> • Employee empowerment • Valuing KS in addition to knowledge • Embedding KM in process • Talent management • Avoid Knowledge Silos • Embed KS into performance evaluation • On-the-job training • Rewarding collective performance rather than individual performance • Management commitment to KM

Category	Insight
	<ul style="list-style-type: none"> Empowering employees with soft skills Learning by teaching Considering knowledge-based intellectual property Validation of knowledge by experts
Content & IT	<ul style="list-style-type: none"> Inefficiency of the current KM system Attention to information security Easy access to the KM system from anywhere Personalized KM system
Strategy	<ul style="list-style-type: none"> Strategy alignment

4.3 Develop

In the third phase, the ideation process commenced, drawing from the insights obtained. Five ideation techniques were employed to generate and explore innovative ideas: reverse and combine from the SCAMPER method, brainstorming, the 666 method, and brain writing were employed to generate innovative ideas. Over 100 initial ideas were generated and reviewed using three lenses (desirability, sustainability, and feasibility), leading to a few final solutions being selected. Prototypes were then developed, tested, and refined through several iterations. Table 2 illustrates the existing problems, previously employed solutions aimed at improving KS but which have yielded unsatisfactory results, and finally, the innovative solutions derived from the integration of KM and DT. Further detailed explanations of each solution are provided below.

Table 2: Summary of problems, previous ideas, and new proposed solutions through the integration of DT and KM.

Problem	Previous ideas/ Solutions	New proposed ideas/ solutions through the integration of DT & KM
<ul style="list-style-type: none"> Difficulty in typing reports Character limits for report entries in the current KM system Potential for forgetting repair details due to the inability to record reports immediately Overlooking the gap between knowledge generation and application 	<ul style="list-style-type: none"> Attaching a Word file to the repair report in the software. Providing requirement to use checklists during repairs 	Solution 1: Easy access and diverse report recording (leveraging technological tools)
<ul style="list-style-type: none"> Loss of knowledge development opportunities due to time constraints, lack of research, study, and trial and error conditions for solving equipment issues. Difficulty of knowledge transfer between novices and experienced workers during key equipment repairs or construction projects. 	<ul style="list-style-type: none"> Training by novices presence of novices alongside experts during key equipment repairs 	Solution 2: Maintenance lab
<ul style="list-style-type: none"> Risk of losing valuable knowledge from experienced staff Insufficient documentation of successful actions and failures Inability to differentiate between high-quality and mediocre work Increased costs due to repeated failures from unshared lessons Lack of a suitable platform for planning informal interactions that foster camaraderie 	<ul style="list-style-type: none"> Holding semi-formal meetings for various occasions, such as working breakfasts Rewarding repair reports that are considered high-quality, outstanding, and valuable by unit managers 	Solution 3: Organizational social network components including: <ul style="list-style-type: none"> - Success stories - Lessons learned from failures - Informal KS circles
<ul style="list-style-type: none"> Infrequent consultation of previous documents and reports due to lack of motivation Inadequate validation or insufficient review of prepared reports Poor quality of generated reports 	<ul style="list-style-type: none"> Requiring the validation of reports produced in each department by the unit head Rewarding high-quality reports as assessed by unit managers 	Solution 4: Creating a collaborative environment for report validation

4.3.1 *Solution 1: Easy Access and Diverse Report Recording (Using Technological Tools)*

The solution utilizes technological tools such as a head camera, voice recorder, and speech-to-text software to record breakdown reports. The advantages of this solution include eliminating the need to type reports after work fatigue and ensuring that no details are overlooked during report recording. In many maintenance departments, their staff often view writing as an adversary, preferring hands-on problem-solving over documentation and formal KS.

4.3.2 *Solution 2: Maintenance Lab*

In maintenance departments, the emphasis is often on quick solutions to return equipment to production rapidly, leaving little room for trial and error, timely KS, or testing innovative problem-solving methods. This research proposes the establishment of a dedicated maintenance lab, which will significantly enhance KS by providing a structured environment for these activities. The maintenance lab will emphasize practical and research-oriented KS, enabling experienced and novice employees to collaborate effectively. By working together, novices can learn from seasoned professionals, facilitating KS and fostering teamwork and collaboration. This approach ensures that valuable knowledge and skills are transferred seamlessly between employees. In the lab, maintenance staff can perform repair maneuvers without risking damage to equipment, allowing for safe experimentation and knowledge generation. The lab's collaborative nature, with teams researching specific topics, will promote a stronger team spirit. Ultimately, the maintenance lab will serve as a hub for KS, where both practical experiences and research insights are shared and developed.

4.3.3 *Solution 3: Organizational Social Network*

This solution involves creating an organizational social network comprising three sections: success stories, failure stories, and informal knowledge circle. Particularly beneficial for novices and newcomers, the solution offers opportunity for sharing successes and failures, with ratings from supervisors and other colleagues. It encourages participation through the review of shared stories, increase the ability to give supplementary suggestions and comments. Knowledge circle offers a platform for sharing experience to enhance informal communication, build empathy, and reduce hierarchical barriers, and build trust.

4.3.4 *Solution 4: Fostering a Participatory Environment for Validation of Reports*

This solution enables report validation and rating by supervisors and other colleagues, with rankings displayed to reflect report quality. All participants in the report validation process receive points, fostering a participatory environment where individuals earn points by reviewing reports, providing supplementary suggestions, commenting, and validating them. The gamification approach to the award system has been integrated in all above-mentioned solutions to provide continuous motivation for engagement.

Simple and scalable prototypes are used instead of final products to examine how users interact with the designed solutions. User interactions and reactions are observed and measured. Prototyping helps avoid the time and cost associated with producing a final product. This study utilized some prototyping tools, such as a storyboard. Notably, the produced prototype, encompassing all proposed solutions, was presented in a focused group session attended by 30 stakeholders, receiving feedback. Each proposed solution was also individually tested and evaluated in various forms (qualitative and quantitative), with results discussed below.

4.4 Qualitative Evaluation

4.4.1 *Solution 1: Easy Access and Diverse Report Recording*

This solution was tested and validated in two iterations: audio recording and video recording using a mobile phone followed by recoding with a GoPro camera during repairs. The repair processes of two pieces of equipment were selected for testing and validation. Tables 3 and 4 summarize the results from in-depth interviews, immersion and iterations.

Table 3: Easy access and diverse report recording (iteration 1-audio recording)

Positive feedback	<ul style="list-style-type: none"> • Faster and easier report recording • Ability to express feelings during the work process by recording audio • Less time is needed for editing the report after converting audio to text compared to typing the entire report
Negative feedback	<ul style="list-style-type: none"> • Inadequate efficiency of solely recording audio reports for certain repairs • Need for editing the transcribed text due to spoken language • Influence of ambient noise, background noise, and noise from others on report quality
Improvement suggestions	<ul style="list-style-type: none"> • Enhance the ability to save images and files in various formats, alongside audio files • Suitable devices to improve the quality of recorded audio.
Actions taken in iterations	<ul style="list-style-type: none"> • Add an option for converting audio to text and enable editing of the transcribed audio reports

Table 4: Easy access and diverse report recording (iteration 2-video recording with mobile phone and headband)

Positive feedback	<ul style="list-style-type: none"> • Faster and easier report recording • Ability to capture all details and repair methods • No need to write down essential repair notes on paper • Transfer of helpful knowledge with little time
Negative feedback	<ul style="list-style-type: none"> • Causing headaches and pressure on the spine due to the weight of the camera on the head • The uncomfortableness of the camera holder • Effect of environmental noise • Need for high camera or mobile memory to record videos • Reluctance to use a head camera due to limitations in attaching hair implants or hair gel
Improvement suggestions	<ul style="list-style-type: none"> • Utilize suitable headgear and Go-Pro cameras for their lightweight nature and built-in stabilization features • Incorporate film editing capabilities • Employ a videographer assistant • Use headgear or camera mounts on pockets or chest straps • Ensure oversight of the quality and quantity of generated content

In the next iterations, head-mounted Go-Pro cameras were utilized due to their lighter weight compared to mobile phones and their advanced stabilization features. This simpler and more efficient equipment increased the likelihood that visual reports were consistently used, enhancing documentation and communication processes.

4.4.2 Solution 2: Maintenance Lab

To test and validate this solution, maintenance employees were asked to use this lab for repairing and testing machine components. The effectiveness of solution was evaluated using in-depth interviews and immersion, with the results summarized in Table 5.

Table 5: Maintenance lab

Positive feedback	<ul style="list-style-type: none"> • Practical learning is more effective than theoretical learning • experienced and novice staff • Possibility of team building with multidisciplinary members • Preventing potential damage from testing on equipment • Possibility for creativity and further learning in repair methods • No time constraints for immediate results • Opportunity for trial and error • Enhancing teamwork and covering each other in order to achieve goals
Negative feedback	<ul style="list-style-type: none"> • Concerns and worries about the volume of daily tasks and routines • Lack of standardization in the environment for conducting specific tests and laboratory conditions • Lack of concentration due to environmental noise
Improvement suggestions	<ul style="list-style-type: none"> • Consider environmental requirements for specific tests. • Ensure all documents and technological facilities are available in the laboratory

4.4.3 Solution 3: Organizational Social Network

This solution consists of two parts: 1) success and failure stories and 2) knowledge circle. To test success and failure stories, a specific group in the organizational social network was used. Initially, the group's purpose was announced to all users via a message from the department's deputy. Recognizing that managers should lead by example in KM and normalize sharing failure experiences, a manager shared a personal failure story. Subsequently, other group members began sharing their success and failure stories. The summary of the in-depth interviews and actions taken in iteration based on observation and analysis is presented in Table 6.

Table 6: Success and failure stories

Positive feedback	<ul style="list-style-type: none"> Facilitates individuals in gaining visibility with managers and colleagues Boosts motivation by allowing individuals to express themselves within the group Offers the opportunity for direct communication with managers Enables appreciation of individuals for their valuable work Serves as a suitable platform to replace individual and group meetings
Negative feedback	<ul style="list-style-type: none"> Lack of active participation in the solution due to insufficient trust and transparent reward mechanisms Fear of being Judged by colleagues Distress and discouragement stemming from the undervaluation of individuals' stories Neglect of the importance of introducing teammates in group narratives Failure to record details of experiences
Improvement suggestions	<ul style="list-style-type: none"> Focus more on improving interpersonal relationships.
Actions taken in iterations	<ul style="list-style-type: none"> Allocate more scores for group stories compared to individual ones. Increase manager participation in documenting stories Assign double scores for documenting failure stories compared to success stories. Establish a specific format for documenting stories

Knowledge circle solution was tested and validated by organizing informal circle focused on discussing various topics. A summary of the in-depth interview results with users is presented in Table 7.

Table 7: Knowledge circle

Positive feedback	<ul style="list-style-type: none"> Effective learning has occurred Improvement in the quality of relationships and better understanding of colleagues and its impact on facilitating KS
Negative feedback	<ul style="list-style-type: none"> The effect of the volume of daily tasks and routine on attendance
Improvement suggestions	<ul style="list-style-type: none"> Create a method for receiving participant feedback Increase manager participation and have them serve as role models in the knowledge circle Foster two-way interaction between presenters and audiences
Actions taken in iterations	<ul style="list-style-type: none"> Hold two sessions led by two managers in a semi-formal setting. Organize at least four more knowledge circles with a larger number of participants Allocate time for discussion and knowledge exchange after presentations

4.4.4 Solution 4: Fostering a Participatory Environment for Validation of Reports

Due to time constraints in this research, testing and validation of this solution were conducted in a focused session and presented to users as a storyboard. User feedback is summarized in Table 8.

Table 8: Fostering a participatory environment for validation of reports

Positive feedback	<ul style="list-style-type: none"> Expressing user satisfaction due to the possibility of increasing scores by studying other people's reports and commenting on them
Improvement suggestions	<ul style="list-style-type: none"> Utilize a monitoring system for the reporting system rating given by users

4.5 Quantitative Evaluation

The quantitative results from the questionnaire are summarized in Table 9.

Table 9: Quantitative results

Measured parameters Solutions	Improvement in KS atmosphere among colleagues	Willingness to share personal knowledge	Increase in personal knowledge compared to before	Recommendation to Implement the solution in other departments	Willingness to continue participation
Maintenance laboratory	61.8%	93%	90.4%	85.6%	100%
Easy access and diverse report recording	71.3%	87.9%	76.1%	77%	65.7%
Organizational social network	60.7%	53.5%	39.2%	86%	78.5%
Knowledge circles	85.4%	57.1%	80.9%	90.4%	90.5%

The quantitative results reveal significant findings: Maintenance Laboratory notably enhanced the KS atmosphere among colleagues, prompting a strong recommendation for implementation in other departments. Easy access and diverse report recording led to substantial improvements in the KS environment, albeit with somewhat lower recommendation rates and willingness to continue participation. Success and failure stories yielded moderate improvements in KS, with a high recommendation rate for implementation elsewhere. The Knowledge Circles concept showed the highest improvements in the KS atmosphere and personal knowledge, supporting its broad implementation across departments. These results affirm the effectiveness of various strategies in bolstering KS and advocate for their widespread adoption.

4.6 Deliver

Based on the results obtained, the solutions incorporating the GoPro camera and Knowledge Circle have successfully advanced to the delivery stage, which is now operational. The remaining solutions require further iterations to reach this stage.

5. Conclusion

The purpose of this research is to enhance KS within the maintenance department of a KIF. Facilitating KM in the maintenance department has consistently been a challenge for KIFs. The expertise and experiences of the staff are considered a major asset in problem diagnosis, failure prevention, and equipment performance improvement. Given the risk of knowledge loss, employing a creative solution to facilitate KM and KS was chosen as the focus of this study.

The innovative solution presented in this paper is using a human-centered DT approach, specifically tailored for solving complex problems. DT combines user desirability with technical feasibility and economic viability to generate innovative ideas. One of the strengths of the DT approach is empathy, which helps identify the real needs of individuals. In this study, three tools—interview, observation, and immersion—were used to empathize with users. The insights gained from these tools led to a reevaluation of the initial problem based on the users' actual needs.

Following the Double Diamond model, a wealth of information was discovered and converged into four categories: People, Process, IT/Content, and Strategy. Ideation then commenced, and all ideas were evaluated through the lenses of desirability, sustainability, and feasibility, ultimately selecting the most effective solutions. The selected solutions were tested and evaluated, yielding significant qualitative and quantitative results.

Based on the research objectives and results, it can be concluded that employing DT can enhance KM and KS within maintenance settings. The study reveals that DT, with its emphasis on empathy and user-centered design, is particularly effective in addressing complex and human-related problems.

Overall, the creative aspect of this paper lies in the application of the DT approach to solving the complex issue of KM and the effective integration of these two concepts. The results demonstrate the effectiveness of using the DT approach in this context. However, it is worth mentioning that the solutions derived are specific to the maintenance department of the reviewed KIF. Other organizations should customize their own KM systems with the DT process to fit their specific needs.

Limitations of study:

- Time-consuming testing and evaluating solutions with multiple iterations in the DT process.
- Limited target population to one company.
- Due to article length constraints, not all solutions could be presented despite their creativity and innovation.

Given the critical role of the maintenance department in maintaining the optimal performance and sustainability of industrial equipment and systems, the high value of the knowledge possessed by employees in this department, and the importance of having an effective KM system, continuing this process is part of this team's future plan. As mentioned in the limitations, further repetition and testing of each solution until optimal results are achieved, remain part of the pathway to the final goals of this research.

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