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Improving Laboratory Safety Through Labee: A Design-Based Approach to a Self-Inspection Application for Researchers*

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Abstract

This study presents the design and development of Labee, a self-inspection laboratory safety application aimed at enhancing researchers' safety awareness and preventing laboratory accidents. Existing laboratory safety management systems are predominantly administrator-centered, limiting researchers' active participation in identifying and managing potential risks. To address this limitation, this study proposes a researcher-driven safety management approach that enables voluntary and routine self-inspection. The study followed the ADDI process—Analysis, Design, Development, and Implementation—based on the ADDIE instructional design model. Domestic and international laboratory accident cases and existing safety management applications were analyzed to identify system requirements, after which a user-centered mobile application was designed and implemented. Labee provides checklist-based self-inspection, real-time feedback, result visualization, and personalized safety education, covering general, chemical, biological, mechanical, electrical, and psychophysiological safety factors. The findings suggest that Labee supports proactive accident prevention by encouraging daily safety practices and improving researchers' engagement in safety management. Furthermore, the system demonstrates potential for expansion into a data-driven and AI-based predictive safety management platform, contributing to the establishment of a sustainable laboratory safety culture.

Keywords : Laboratory Safety, Self-Inspection, Mobile Application, Risk Management, Labee

1. Introduction

1.1. Research background

Laboratories are spaces that require a high degree of expertise and precision, and are also high-risk environments that handle a variety of chemicals and

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experimental equipment. In particular, laboratories in the fields of chemistry and chemical engineering present a high risk of serious accidents, such as hazardous substance leaks, burns, and explosions, which not only cause casualties but also significantly impact the continuity of research. According to Article 2, Paragraph 12 of the Act on the Promotion of a Safe Laboratory Environment, a "laboratory accident" refers to an accident in which a researcher suffers injury, illness, disability, or death during research activities, or in which laboratory facilities or equipment are damaged. According to the 2024 Laboratory Safety Management Survey, there are significant disparities in the rate of laboratory accidents by institution type [1]. Universities had an accident rate of approximately 9.85% (33 out of 335 institutions), while research institutes had the highest rate of accidents at 17.28% (33 out of 191 institutions). This figure is approximately 1.75 times higher than that of universities, indicating that research institutes frequently perform high-risk experiments and operate complex equipment. In contrast, companies and R&D departments showed the lowest accident rate at 1.18%, with accidents occurring in 48 out of 4,080 institutions. In 2025, at a domestic research institute, an accident occurred in which a researcher suffered burns when a leaked nitric acid solution came into contact with his body during the process of dispensing the solution using a pipette. This accident was caused by a combination of factors such as improper handling of experimental equipment, failure to wear protective gear, and an inappropriate work environment. According to the "National Research Safety Information System Laboratory Accident Casebook," the main cause of accidents over the five years from 2019 to 2023 was "misuse or non-use of protective gear" (412 cases), followed by "failure to prepare or non-compliance with safety rules" (264 cases) and "lack of experience and training" (257 cases). This suggests that, regardless of the type of institution, a lack of basic safety awareness among researchers is a key factor in laboratory accidents. Since most laboratory accidents are preventable, a systematic safety inspection system that considers the characteristics and types of accidents of each institution is necessary. Furthermore, there is a pressing need for self-inspection-based management tools that enable researchers to independently assess their safety status and identify risk factors.

1.2. Status of self-diagnosis applications

1.2.1. Current Status of Domestic Laboratory Safety Management Applications

Representative applications related to laboratory safety management and education in Korea include Lab SAFE

from the National Research Safety Management Agency, Pohang University of Science and Technology's Laboratory Safety Information Network, and Smartjack Co., Ltd.'s Lab Manager PRO. Lab SAFE manages potential hazards during research activities and provides safety information. It includes functions for routine inspections using legally-designed forms, QR code-based hazard information searches, safety training materials, and accident case sharing. While highly useful for providing a variety of integrated safety information, its voluntary inspection and feedback capabilities for researchers are limited.

Pohang University of Science and Technology's Laboratory Safety Information Network is a web-based safety management portal that provides mobile safety education and lab-specific safety information. While it visually presents building-specific safety status and photographic data through a map-based interface, it remains a management-centric inspection system, lacking self-diagnosis capabilities for individual researchers.

Lab Manager PRO is a commercial application specialized in reagent and supplies management. It offers AI-based reagent recognition and inspection registration, real-time MSDS access, and storage location management. However, they are more focused on asset management than safety inspections. Domestic laboratory safety management applications focus on providing information and administrative support, and lack self-inspection features that allow researchers to independently assess and improve their safety levels.

1.2.2. Current Status of Safety Management Applications in Overseas Laboratories

Major overseas laboratory safety management applications include the Fulcrum Laboratory Safety Checklist App and Assessment. The Fulcrum Laboratory Safety Checklist App is a mobile checklist-style application for laboratory safety inspections, designed to allow researchers to select and check items. However, its generalized structure does not adequately reflect national safety regulations or the specific characteristics of each research field.

Assessment includes functions for self-inspection of risks, provision of a personal protective equipment (PPE) list, and management of employee training history. However, its lack of data-driven risk analysis and customized feedback capabilities hinders its expansion into a sustainable safety management system. Domestic and international laboratory safety management applications focus on limited functions such as information provision, education, and material management. Self-inspection applications that enable

researchers to proactively identify risk factors and implement preventive measures are lacking.

1.3. The need for research

While a laboratory safety management system is established based on legal and institutional foundations, the establishment of a practical safety culture remains inadequate. Given that the primary causes of laboratory safety accidents stem from the negligence and lack of safety awareness among researchers, simple compliance-focused management has limitations. Existing laboratory safety management systems operate primarily through inspections by institutions or managers, making it difficult to develop into a voluntary management system where researchers actively recognize risks and take action. Furthermore, the separate training, inspection, and reporting processes limit real-time sharing and feedback on safety information. Therefore, a digital-based management system is needed that enables researchers to self-inspection and improve their work environments. Self-inspection safety management tools are considered an alternative that can increase researcher participation and enhance the effectiveness of safety management.

To address the limitations of existing management systems, this study proposes the development of a laboratory safety self-inspection application that enables researchers to voluntarily assess their laboratory safety level and identify improvement measures. Through this, we aim to identify potential risk factors in the laboratory in advance, improve safety awareness among researchers, and contribute to preventing laboratory accidents. We also propose a laboratory safety self-inspection application model that allows researchers to self-inspection their own work environment and improve safety levels.

2. Main Thesis

2.1. Research Introduction

This study proposes "Labee," a self-diagnostic laboratory safety application aimed at enhancing safety awareness and preventing accidents in research environments. "Labee" is a portmanteau of "lab" and "bee" (a diligent bee), symbolizing researchers who diligently monitor and manage laboratory safety. This application is designed to address the limitations of existing manager-centered safety management, enabling researchers to independently inspect, analyze, and improve their experimental environments. Through mobile-based checklists and real-time feedback, it establishes a self-directed safety management system, aiming to foster a

culture of safety within laboratories and minimize the risk of accidents.

2.2. Research methods

The four-step procedure of this study was grounded in the ADDIE model (Analysis, Design, Development, Implementation, Evaluation), and the ADDI (Analysis, Design, Development, Implementation) process was applied excluding the evaluation stage to focus on the initial design and implementation of the system.

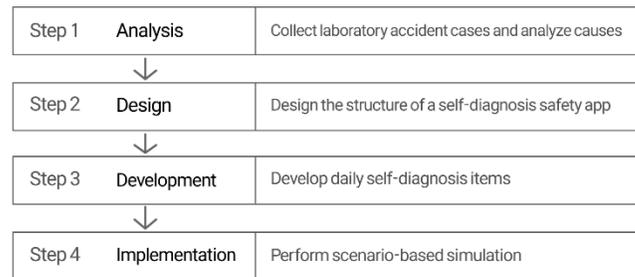


Figure 1: Research Flowchart for the Development of a Laboratory Safety Self-Inspection Application

1. Analysis

By comprehensively analyzing domestic and international laboratory accident cases and existing safety management applications, we identified key requirements and improvement directions that formed the basis for the development of "Labee."

2. Design

Based on the analysis results, we systematically designed a user-centered structure and functions, establishing a foundation for self-directed and efficient laboratory safety management.

3. Development

We developed a multidimensional self-inspection tool that encompasses the physical and mental health of research workers, aiming to complement the limitations of existing safety management.

4. Implementation

We verified the system's feasibility and field applicability through simulations based on operational scenarios.

2.3. Self-Inspection composition plan

The core function of "Labee," developed in this study, is a self-inspection system routinely performed by researchers. It consists of five core areas aimed at preventing accidents and enhancing safety awareness in research environments. Each item is designed in a "yes/no" format to encourage risk awareness and corrective action.



Figure 2: Storyboard for Researcher Safety Self-Inspection Application

1. General Safety

Check the laboratory environment, personal protective equipment(PPE), and emergency response systems to ensure compliance with basic safety rules.

2. Chemical Safety

Prevent accidents related to hazardous chemicals by inspecting chemical management, warning signs, and disposal procedures.

3. Biological Safety

Minimize the risk of infection and contamination by inspecting biological handling, sanitary equipment, and disposal plans.

4. Mechanical, Fire, Electrical Safety

Control physical hazards associated with complex equipment by inspecting mechanical, electrical, and firefighting equipment.

5. Researcher's Psychophysiological State

Mimize the risk of accidents caused by researcher attitudes and lack of concentration by assessing the physical and mental condition of researchers, thereby supporting safe research.

2.4. Application configuration

2.4.1. Application start screen and manual

The "Labee" start screen features a video tutorial to help researchers easily understand and utilize the application. The manual consists of six core functions: researcher login, lab self-inspection, lab evacuation map, Q&A, results reporting, and lab safety education. The manual allows researchers to visually review their assessment scores, allowing them to understand their safety level at a glance and immediately identify areas for improvement. Scores translate abstract safety status into quantitative data, strengthening self-awareness and encouraging ongoing behavioral change. Furthermore, the results are presented in graph form, allowing for comparison and analysis of safety inspection trends, enabling a systematic and data-driven assessment of lab safety management. The lab safety training function enhances the safety capabilities of researchers by providing personalized content focused on areas of weakness based on individual assessment results.

This structure fosters a practical safety management system through self-directed researcher participation and data-driven feedback.[Figure 3].



Figure 3: Lab Safety Self-Inspection Application Start Screen and Manual

1. Researcher Information

The researcher login screen verifies user identity by searching for labs and confirming researcher information, and grants permission to participate in safety inspections.[Figure 4].

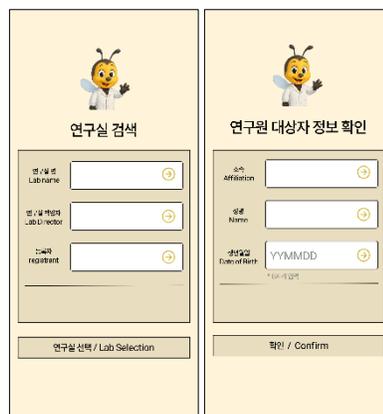


Figure 4: Researcher Information

2. Consent to collection and use of personal information

The personal information collection and use consent screen is designed to clearly confirm consent to participate in safety inspections, prioritizing the protection of researchers' personal information.[Figure 5].

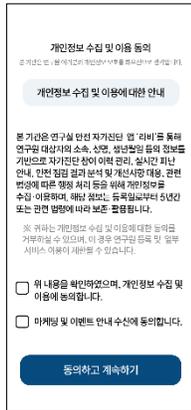


Figure 5: Consent to collection and use of personal information

3. Laboratory Safety Self-Diagnosis

The laboratory safety self-inspection system is designed to enable researchers to proactively inspect and document all essential safety items, including daily free checks and key experimental steps (organic synthesis, solvent heating, and reactions, microbial culture and handling, and high-pressure gas and cylinder use). This allows researchers to systematically perform routine inspections and pre-experiment safety checks, minimizing the risk of laboratory accidents.[Figure 6].



Figure 6: Laboratory Safety Self-Inspection

4. Daily Pre-Check

Daily Pre-Check consists of five core areas: general safety, chemical safety, biological safety, mechanical, firefighting, and electrical safety, and researcher personal health. It provides a mobile checklist for proactive safety management, available in various languages, allowing researchers to systematically review and record essential safety items daily. This allows researchers to comprehensively assess and manage their overall safety status, encompassing not only physical, chemical, and

biological hazards but also physical, mental, and social well-being, thereby preventing laboratory accidents.

(a) General Safety

- Is the laboratory area clean and tidy?
- Is there no eating, drinking, or smoking in the laboratory?
- Are the necessary personal protective equipment (safety glasses, gloves, etc.) being worn properly?
- Are safety rules, warning signs, and first aid kits clearly visible and accessible?
- Are you familiar with the emergency contact system and evacuation routes?

(b) Chemical Safety

- Are the hazardous chemicals to be used today recorded in a management log?
- Are chemicals classified by type and stored in a safe location(e.g., reagent cabinet)?
- Are warning labels attached to hazardous chemical storage containers?
- Is there a plan to dispose of waste liquids and waste after the experiment in a designated manner?
- Are carcinogens and toxic substances isolated and locked?

(c) Biological Safety

- Are sanitary equipment, such as hand sanitizers and autoclaves, functioning properly?
- Are the biological handling facilities clean and access restricted?
- Will equipment handling biological materials be cleaned after the experiment, and will medical waste be disposed of separately?
- Are biohazardous materials stored in sealed containers?
- Are the necessary personal protective equipment (masks, gloves, etc.) worn during biological experiments?

(d) Machinery, Firefighting, and Electrical Safety

- Are the fasteners and connections of the machines and tools used in the experiment intact?
- Are unused electrical equipment turned off?
- Are there any foreign objects or obstacles around the electrical distribution board?
- Are fire extinguishers clearly marked and in a visible location and have they been inspected?
- Check the pressure and expiration date of the fire extinguisher and ensure they are in good condition?

(e) Researcher's Condition

- Are you physically tired or in pain today?
- Are you feeling severe mental stress or having difficulty concentrating?
- Do you have a fever or other physical symptoms? (e.g., dizziness, headache, nausea, etc.)

- Have you ever experienced or anticipated any sudden changes in your physical condition during the experiment?
 - Are you in a condition to safely conduct the experiment today? [Figure 7].



Figure 7: General safety & chemical safety biological safety & mechanical & firefighting and electrical safety & researcher's own status

5. Participate in self-diagnosis

Participating in today's self-assessment will guide researchers to complete daily lab safety checks, identify and document any abnormalities. This will allow researchers to systematically monitor and document their own condition and the experimental environment, enabling them to practice daily safety management and accident prevention while maintaining awareness of their own condition.[Figure 8].



Figure 8: Participate in the lab Self-Inspection

6. Evacuation map for each lab

Evacuation maps for each lab provide visual guidance to researchers, enabling them to confirm evacuation routes before beginning research and respond quickly in emergencies. This allows researchers to maximize evacuation speed and response efficiency in the event of an accident, protecting themselves and their labs from safety hazards.[Figure 9].



Figure 9: Lab Evacuation Guide

7. Q&A

The Q&A screen provides a non-face-to-face communication platform where researchers can quickly report issues, improvement plans, and simple inquiries, and receive real-time feedback and customized risk analysis from managers. This allows users to enhance real-time decision-making and risk management capabilities, enhancing the speed and expertise of laboratory safety management.[Figure 10].



Figure 10: Laboratory Safety Self-Inspection Questions and Answers

8. Results Report

The results reporting screen was designed to intuitively display the results of the lab's self-assessment, referencing the structure of the "Hada" application, which visually manages individual goal achievement. It visualizes the lab's self-inspection status by month, quarter, and the last seven days, allowing for at-a-glance review. A calendar-based color coding distinguishes labs by self-inspection status: completed, partially completed, not yet completed, and scheduled. This allows managers to systematically analyze the progress and performance of safety management and efficiently assess the lab's overall safety level. In the future, the system is designed to be expanded into a data-driven, real-time analysis and feedback system through integration with corporate safety management solutions or private technology collaboration.[Figure 11].



Figure 11: Self-Inspection Result Report

9. Laboratory Safety Training

The Lab Safety Education screen is designed to efficiently provide researchers with the necessary safety knowledge, including the Lab Safety Act, the National

Research Safety Information System, major accident cases, and customized safety training. Researchers can easily access laws and educational content, enhance safety awareness through major accident cases, and continuously improve safety competencies through personalized training recommendations based on self-assessment results.[Figure 12].



Figure 12: Laboratory Safety Education

3. Conclusion

This study proposes "Labee," a laboratory safety self-inspection system, to enhance safety awareness and prevent accidents among researchers. While existing laboratory safety management relies primarily on manager-centered inspections and post-event responses, this system aims to establish a preventative safety management system through a daily self-assessment process in which researchers directly participate. "Labee" monitors various factors, including the physical condition of researchers, the experimental environment, and chemical, biological, electrical, and mechanical safety, in real time before conducting research activities. This system can prevent accidents in advance and improve compliance with safety regulations within the laboratory. Furthermore, inspection results are automatically saved, increasing the efficiency of institutional safety management records and legal reporting procedures. This system can also contribute to fostering a safety management culture where managers and researchers share responsibility. Specifically, repetitive safety checks through self-inspection routinely encourage researchers to adopt safe behaviors and view safety as an essential part of research rather than a regulatory requirement. This shift in perception is expected to have a short-term impact on accident prevention and, in the long term, to foster a voluntary and sustainable laboratory safety culture.

Furthermore, by analyzing accumulated diagnostic data, risk factors can be quantitatively identified for each experimental field. This system can be further developed into a predictive accident prevention system utilizing artificial intelligence (AI).

Furthermore, this system not only enhances the efficiency of laboratory safety management through data-driven analysis and visualization, but also offers the potential for integration with safety management platforms in the private sector. This opens up possibilities for industrial applications, such as establishing collaborative systems between public institutions and companies and developing customized safety solutions, thereby evolving into a new paradigm for laboratory safety management.

In conclusion, the "Labee" system proposed in this study presents a proactive accident prevention system centered on the participation of researchers. It not only fosters a culture of laboratory safety and enhances facility safety management, but also serves as a practical safety management model with potential for industrial expansion.

Acknowledgements

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References

- Choi, J. E., et al. (2008). Laboratory risk assessment using a checklist-based approach. In *Proceedings of the Korean Society of Safety Conference*.
- Cho, Y. S., et al. (2018). Factors influencing the status and performance of laboratory safety management. *Journal of the Korean Society of Safety*.
- Jang, Y. H., et al. (2019). Establishment of safety grading criteria for university laboratory management. *Journal of the Korea Society of Hazard Mitigation*.
- Kim, D. Y., et al. (2017). Development and statistical analysis of a self-diagnosis application. *Journal of Information Processing Systems*.
- Kim, G. H., et al. (2011). Development of a standardized checklist to prevent electrical accidents in laboratories. *Journal of Electrical Engineering & Technology*.
- Kim, S. Y., et al. (2013). Risk factor analysis in research laboratories using 4M and HAZOP techniques. *Journal of the Korean Society of Safety*.
- Korean Society of Safety Design. (2022). Improvement of laboratory risk assessment methodologies. *Journal of Safety Design*.
- Lee, E. J., et al. (2021). Improvement of safety inspection and in-depth safety diagnosis systems for research laboratories. *Journal of Safety and Health*.
- Lee, H. J., et al. (2020). Risk communication models using smart safety management systems. *Journal of Safety Management and Science*.
- Molenda, M. (2015). In search of the elusive ADDIE model. *Performance Improvement*, 54(2).
- National Research Safety Information System. (n.d.). *Laboratory accident case studies*.
- Park, I. S., et al. (2019). Improvement strategies for routine safety inspections in university laboratories. *Journal of the Korea Academia-Industrial Cooperation Society*.
- Park, M. J., et al. (2016). Self-diagnosis algorithms and mobile applications for global traditional medicine pattern identification. *Journal of Medical Systems*.
- [Government agency]. (2024). *Laboratory safety management status survey report* (Table 4-103).