Academic Education Publishing House
Higher Education and Practice Vol. 3 No. 6, 2026

Construction and Informatization Practice of Safety Management System in University Mechanical Experimental Center

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Abstract: Mechanical laboratories in colleges and universities involve many types of equipment and high-risk operations. Safety management is an important basis for ensuring the orderly development of experimental teaching and scientific research. Aiming at the problems existing in the safety management of mechanical experimental centers in colleges and universities, such as imperfect evaluation standards and insufficient informatization, this paper constructs an experimental safety evaluation index system covering the experimental environment, equipment operation, personnel operation, and other dimensions; Based on this, the university laboratory information management platform based on WeChat applet is designed and built, which realizes the online operation of safety inspection, hidden danger reporting, training assessment, and other functions; Meanwhile, a long-term safety management mechanism of "prevention–monitoring–feedback" closed-loop linkage has been established. Practice shows that this mode effectively improves the safety management efficiency and risk prevention and control ability of the experimental center, and provides a reference paradigm for the laboratory safety management of similar universities.

Keywords: Mechanical Experimental Center; Safety Assessment; Information Management Platform; Safety Management Mechanism

1. Introduction

The university laboratory undertakes the dual tasks of education, teaching, and scientific research. It is not only a base for cultivating innovative talents with practical abilities, but also an important place for the integration of industry, university, and research. Its safety management and accident prevention and control are very important. In recent years, university laboratory safety accidents have occurred from time to time, which is partly due to the weak safety awareness of managers and users and the lack of potential safety hazard prevention and control capabilities. In this regard, the Ministry of Education issued the Opinions on Strengthening the Safety Work of University Laboratories in May 2019, which puts forward clear requirements for the safety work of university laboratories across the country. However, as an important platform undertaking the teaching task of mechanical-related experiments and training in universities, the supporting safety management system of the mechanical experimental center in colleges and universities still needs to be improved: the safety regulations are too broad and lack systematicness and pertinence; a lack of disciplinary measures in the implementation of the system leads to insufficient binding force; the lack of long-term and systematic safety education easily leads to paralysis and a fluke mentality among teachers and students; the lack of safety knowledge among laboratory personnel further increases the risk of accidents [1,2]. Based on this, combined with the current situation of the safety management of the mechanical experimental center in colleges and universities, through continuous practice and optimization, this paper proposes a new safety management model with strong applicability and wide coverage, in order to further improve the safety management level of the experimental center.

2. Problems in Safety Management of Mechanical Experimental Center

The mechanical experimental center is mainly responsible for the experimental teaching of courses inside and outside the college, and provides important support for teachers' and students' scientific research and competitions. Due to the wide variety of laboratory teaching and research venues and instruments and equipment, and the wide range of safety management, there are still many problems to be

solved.

2.1 Laboratory Safety Assessment Index System Is Not Quantified

The current safety assessment system is not comprehensive and lacks quantitative indicators, resulting in loopholes in the management of management institutions, environmental safety, hazardous chemicals management, three-waste disposal, water and electricity safety, fire and theft prevention, experimental data, and equipment operation [3]. First, risk identification is insufficient, and it is difficult to comprehensively quantify the potential risks of fire and explosion, mechanical injury, electrical safety, etc.; second, the preventive measures lack pertinence, and it is difficult to scientifically formulate protective equipment standards, operating procedures, and emergency plans; third, the boundary of safety responsibility is fuzzy, which affects the implementation of the responsibility system; fourth, there are hidden dangers in compliance, making it difficult to meet the requirements of national laws and regulations and industry norms.

2.2 Imperfect Rules and Regulations or Ineffective Implementation

The laboratory lacks a perfect safety management system and operating procedures, or although there are systems, the implementation is a mere formality, and strict management of all staff, the whole process, and all aspects is not achieved. First, potential safety hazards increase; the lack or lax implementation of operating procedures can easily lead to fire, trauma, and other accidents, threatening the safety of personnel; second, equipment loss is increasing, and the lack of strict operation, maintenance, and repair specifications leads to excessive equipment loss and frequent misoperation, which shortens the service life and increases the maintenance cost, and even affects the accuracy of experimental data.

2.3 Insufficient Safety Education and Training

Laboratory personnel have insufficient awareness of hazardous sources such as chemicals and mechanical hazards, a lack of emergency treatment knowledge, and a lack of systematic regular training. First, there is a lack of basic knowledge; personnel do not have a deep understanding of safe operation procedures, first aid knowledge, chemical properties, and mechanical safety, and tend to respond slowly or improperly in case of emergencies; second, skills training is inadequate; personnel find it difficult to master equipment operation and hazardous material handling methods, and the risk of misoperation increases; third, emergency response capabilities are weak, and there is a lack of emergency plan drills, which makes it impossible to respond quickly and effectively in case of emergency; fourth, awareness of laws and regulations is weak and compliance training is insufficient, which easily leads to legal liability; fifth, there is a lack of continuous education, and the understanding of new risks and best practices lags behind.

2.4 Inadequate Safety Facilities

The laboratory safety facilities are not complete, maintenance is not timely, and the safety signs are unclear or missing. For example, supporting measures such as safety warning lines, electrical safety signs, high-temperature warning signs, mechanical injury warning signs, safety exit signs, first-aid kits, and regular equipment maintenance failed to achieve full coverage of risk points. These facilities integrate safety requirements into every operational detail, which is an important material basis for on-site safety protection. Their lack or failure directly weakens the ability of risk early warning and emergency response.

2.5 Nonstandard Operation Process

Some experimenters fail to strictly abide by the safety regulations during operations and ignore the risk assessment and hazard identification before the experiment. Such non-standard operations can easily expose personnel to toxic and harmful substances, causing direct injuries such as chemical burns, cuts, electrical shocks, and even serious safety accidents such as fire and mechanical trauma. Meanwhile, experimental materials, reagents, and precision equipment may be damaged or rendered invalid due to misoperation, which will not only cause economic losses, but also affect the progress of teaching and scientific research.

2.6 Imperfect Emergency Plan

The laboratory lacks a special emergency plan for fire, chemical spills, mechanical injuries, and other sudden safety accidents, or although the plan has been formulated, practical drills are not

regularly organized. Once a real accident occurs, it is difficult for on-site personnel to quickly initiate the response mechanism and effectively organize evacuation, rescue, and on-site disposal, resulting in delayed emergency response and an expanded impact of the accident, which seriously restricts the ability of self-rescue and mutual rescue in emergencies.

2.7 Single Safety Education Mode

The simplification of teaching methods fails to meet the learning needs of different individuals, and some personnel cannot fully understand and master safety knowledge, which affects the effectiveness of actual operation. Long-term use of the same model easily leads to students' boredom and resistance, reduces their level of active participation, and is not conducive to the formation of lasting safety awareness. If they only remain in theoretical instruction and lack diversified means such as simulation practice and case analysis, they are likely to handle real situations inappropriately due to lack of practical experience.

2.8 Information Platform Is Not Built

The lack of an information platform has brought many management difficulties: first, safety inspection relies on paper records and mobile phone photos, which makes it difficult to realize the information management of hidden danger rectification tracking and accident tracing; second, safety education is a mere formality; personnel lack safety prevention knowledge, and the ability to deal with emergencies is insufficient; third, in terms of experimental teaching management, credit-based course selection leads to cumbersome teaching arrangements and low management efficiency; fourth, the management of instrument and equipment consumables is complicated, which affects the efficiency of equipment use.

To solve the above problems, we need to improve the safety management system, strengthen education and training, improve the hardware facilities, standardize operational behavior, optimize the emergency plan, and build an information platform to comprehensively strengthen laboratory safety management, and effectively ensure the personal safety of teachers and students and the order of teaching and scientific research.

3. New Mode of Safety Management in Mechanical Experimental Center

In order to ensure the safe and smooth conduct of experiments, combined with the actual situation of the professional laboratory of the mechanical engineering experimental center, the following new methods of safety management are formed through continuous exploration and practice.

3.1 Develop and Quantify Laboratory Safety Assessment Index System

The "five-in-one" model is adopted to build the evaluation system around the management organization, environmental safety, hazardous chemicals, three-waste disposal, water and electricity safety, fire and explosion prevention, experimental data, and instrument and equipment operations, with reference to the laboratory safety inspection item list of colleges and universities [4]. Experts are invited to score, and Yaahp software is used to quantify the scores and scientifically determine the weight of indicators at all levels, improve the content of corresponding documents, and form a quantifiable and operable evaluation tool. The system covers five primary indicators: safety responsibility system, i.e., clear organizational structure and division of responsibilities; rules and regulations for standardizing daily management and emergency response; education, training, and access, strengthening ability improvement and risk preemption; safety inspection for realizing process control and hidden danger closed-loop management; and experimental site safety, as well as hardware conditions and operation specifications. Each indicator is refined to the second and third levels and given weights, so that the safety assessment has a basis and rules to follow. Key indicators of safety management system and education are shown in Table 1. Key indicators of safety inspection and laboratory site are shown in Table 2.

Table 1. Key Indicators of Safety Management System and Education

No.	Indicator	Weight
1.1	Safety Work Leading Group	0.0374
1.3	Department/School Responsibility Agreement	0.0259
1.7	Self-raised Funds	0.0217
2.1	Safety Management System	0.08
2.2	Safety Management Measures or Detailed Rules	0.08

2.3	Emergency Plan	0.04
3.1	Safety Education and Training	0.0395
3.3	Safety Knowledge Examination	0.0395
3.4	Safety Culture	0.0261
3.6	Project Safety Risk Assessment	0.0622

Table 2. Key Indicators of Safety Inspection and Laboratory Site

No.	Indicator	Weight
4.1	Hazard Distribution List	0.0167
4.2	Warning Signs	0.0167
4.3	Risk Assessment and Emergency Plan for Major Hazards	0.0333
4.4	Safety Inspection and Self-Inspection	0.0444
4.5	Special Inspection	0.0222
4.6	Hazard Rectification	0.0667
5.3	Fire Access Clearance	0.009
5.6	Environmental Hygiene	0.0189
5.8	Firefighting Equipment and Training	0.0189
5.10	Electrical Safety	0.0189
5.20	Use of Large-scale and Special Equipment	0.008
5.23	Personal Protection for Mechanical Equipment	0.0085

3.2 Improve the Examination Contents of Safety Education and Training

The learning link platform is used to integrate the functions of online training and examination, expand the number and coverage of the question bank, and require all students and teachers who undertake experimental teaching and scientific research tasks to participate in online training and examination. According to the evaluation index system, we have refined the experimental safety content, and produced a series of short videos for micro-lessons, which were uploaded to the platform, covering topics such as instructions before the experimental class, safe use of equipment, material clamping, fire extinguisher operation, room hygiene, post-class instructions, chemical reagent operation, and waste liquid treatment. Teachers and students must complete online learning before applying for the use of the laboratory, and can obtain the qualification for use only after passing the safety admittance examination. Meanwhile, safety education is written into the experimental teaching materials, and the precautions for each experimental project are placed at the beginning, so as to strengthen memory and develop habits.

3.3 Refine the Hidden Danger Screening Mechanism

The screening mechanism is refined from the whole process of experimental teaching and daily inspection. First, teaching is monitored throughout the entire process; the instructor identifies, reports, and rectifies potential hidden dangers in real time at various stages of pre-class preparation, in-class implementation, and after-class closure according to the safety evaluation index system, so as to achieve risk preemption and prevention first; second, daily inspection by classification is carried out. The daily inspection of the laboratory is carried out according to the standardized flow chart, and the inspection frequency, responsible parties, and rectification time limit are defined, so that the inspection is more standardized and hidden dangers are easier to find. Through the establishment of a closed-loop management process of "troubleshooting – recording – rectification – review," the institutionalization and normalization of hidden danger screening are achieved to ensure the timely discovery, effective disposal, and prompt resolution of safety problems.

3.4 Enrich the Safety Education Mode

Breaking away from the single theoretical teaching mode, we adopt multiple forms, such as special lectures, theme class meetings, firefighting and evacuation drills, class safety committee training, and college student safety knowledge competitions, to enhance the interaction, pertinence, and effectiveness of safety education. Informational content such as safety rules and instrument operation specifications is posted in prominent positions in the laboratory, and personalized visual designs are created to form a strong visual impact and improve the attention and alertness of teachers and students. Meanwhile, we establish a mechanism for reporting and feedback of potential safety hazards, encourage teachers and students to participate in the construction of the safety culture, create a good atmosphere in which everyone attaches importance to safety and everyone participates, and promote the transformation of safety awareness from passive acceptance to active practice.

3.5 Construction of Laboratory Information Platform Based on WeChat Applet

We design and develop the "Mechanical Engineering Practical Safety" information

platform based on WeChat applet, adopting the front-end and back-end separation architecture, providing back-end services with Node.js combined with Koa framework, using MySQL to store data, and Vue.js to develop the back-end management interface, so as to realize low-cost, cross-platform, installation-free, and convenient applications [5]. The platform consists of four modules: experimental teaching management, safety management, instrument and equipment consumables management, and safety accident push. It provides functions such as course schedule queries, laboratory appointment, key and tool borrowing, accident message push, and equipment operation specification viewing for teachers and students; it provides background functions such as data entry, hidden danger viewing, and user management for managers [6-10]. After the platform was launched, it has operated stably, and more than a thousand teachers and students have used it conveniently. It effectively has improved management efficiency, promoted resource sharing, and helped the laboratory safety management move towards standardization, refinement, and scientific management. The flow chart of laboratory informatization platform is shown in Figure 1.

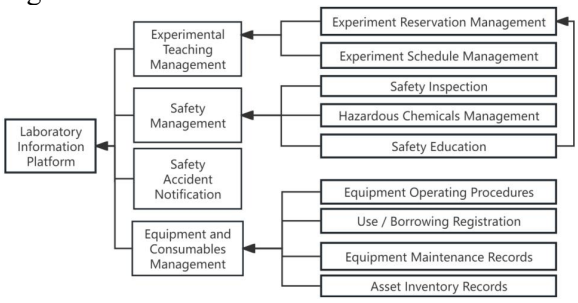

Figure 1. Flow Chart of Laboratory Informatization Platform

4. Conclusion

This paper organically integrates modern Internet technology and traditional laboratory management models, systematically analyzes the specific contents and measures of laboratory safety management at all levels, constructs the safety evaluation index system of the experimental center, revises and improves the laboratory safety management system, builds the university laboratory information management platform, and realizes the institutionalization, systematization, and informatization of safety management. The platform provides convenient, efficient, and safe laboratory management services for college teachers and students, significantly improves the level of laboratory safety management, and effectively ensures the smooth development of experimental teaching and scientific research.

Acknowledgments

This work was jointly supported by Horizontal Research Project of Jingchu University of Technology (Grant No. HZ26001), the Jingmen Science and Technology Think Tank Project (Grant No. 202621), and the College Student Innovation Training Program of Jingchu University of Technology (Grant No. S202511336057).

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