Exploration and Practice of Safety Education in University Teaching Laboratories

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Abstract: *Laboratories serve as a crucial practical platform for teaching and research in universities, constituting a core component of both education and scientific inquiry, and undertaking the vital responsibility of cultivating students' practical and innovative abilities. Conducting laboratory safety education for university students is an effective measure to ensure laboratory safety, while a scientific safety education system serves as a prerequisite for guaranteeing educational outcomes. Through an analysis of the current research status and background of safety education in university teaching laboratories, this paper constructs a safety education system for chemistry teaching laboratories in universities. It proposes a safety education framework tailored to the characteristics of chemistry teaching laboratories in higher education institutions, aiming to contribute strength and insight toward fortifying laboratory safety defenses and building a safe campus.*

Keywords: *Teaching Laboratories; Safety Education; Laboratory Safety*

Introduction

Laboratories serve as a critical practical platform for teaching and research in universities[1], constituting a core component of both education and scientific inquiry, and bearing the significant responsibility of cultivating students' practical and innovative capabilities. With the continuous development of academic disciplines in higher education, laboratory scales have expanded, and their functions have become more diversified; however, new issues and challenges have also emerged. These include incidents such as fires and explosions, which endanger the safety of teachers and students and can lead to substantial economic losses. According to incomplete statistics, over 88% of laboratory safety accidents are caused by unsafe human behavior[2]. Therefore, conducting laboratory safety education is particularly important.

In recent years, the Ministry of Education has issued multiple documents requiring the strengthening of laboratory safety education in universities. In February 2017, the "Notice on Strengthening Safety in University Teaching Laboratories" explicitly proposed "enhancing laboratory safety emergency response capabilities and consolidating the foundation of laboratory safety work". In January 2019, the "Notice on Further Strengthening Safety Inspections in University Teaching Laboratories" called for "strengthening safety education for teachers and students in laboratories, and raising their awareness of laboratory safety as well as their ability to implement safety protections". In December 2021, the "Notice of the General Office of the Ministry of Education on Carrying out Special Actions to Strengthen Laboratory Safety in Universities" required the reinforcement of laboratory safety education systems. In February 2023, the issued "Safety Standards for University Laboratories" stipulated that universities dealing with significant hazard sources should establish credit-bearing laboratory safety courses or integrate safety access education and training into the academic cultivation process, thereby establishing and improving laboratory safety education, training, and access systems. Consequently, it is highly necessary to advance safety education and reform in university teaching laboratories.

1. Analysis of Research Status and Background

1.1 Current Status of Laboratory Safety Education in Domestic Universities

Laboratory safety education in Chinese universities started relatively late, with the safety engineering major being established in 1984. Currently, nearly 200 institutions offer this program. In

June 1989, Chen Xingbiao et al. published Laboratory Safety Technology, which became China's first laboratory safety manual and a primary textbook for laboratory safety education. Subsequently, various universities have also carried out safety education initiatives and reforms. For instance, Tsinghua University designed and compiled the "Tsinghua University Laboratory Safety Manual" in 2003, made "Laboratory Safety Science" a compulsory course for graduate students in 2004, adopted a safety education and examination system in 2008 which was successfully implemented at universities such as the University of Science and Technology Beijing, Wuhan University, and Nankai University, began offering laboratory safety courses in 2015 targeting key safety issues in chemical laboratories and providing comprehensive training to strengthen students' safety awareness, and published the Tsinghua University Laboratory Safety Examination Question Bank in 2018. Other universities, including Peking University, Zhejiang University, Tianjin University, and Beijing Institute of Technology, have also conducted research on laboratory safety education and reform, introducing modern teaching methods to enhance students' laboratory safety awareness[3].

1.2 Content and Forms of Laboratory Safety Education

1.2.1 Content of Laboratory Safety Education

It encompasses safety aspects related to chemicals, biology, fire protection, water, electricity, gas, mechanical equipment, radiation, and special equipment. This content is broad in coverage and distributed across various specialized disciplines. Safety knowledge for chemical laboratories is particularly extensive and fragmented. It includes the safe storage, use, recycling, and disposal of hazardous chemicals, as well as the safe operation of instruments, equipment, and utilities like water, electricity, and gas. Concurrently, safety knowledge also pertains to personal protective equipment, public safety, environmental and ecological protection, accident prevention, and emergency response procedures for unexpected incidents.

1.2.2 Forms of Laboratory Safety Education

Laboratory safety education is primarily delivered through teacher-led classroom instruction, with the content largely focused on knowledge points required for examinations. Students mostly receive this knowledge passively, lacking the initiative for active learning, which makes it difficult to meet the vocational skill requirements of modern industries. With the rapid advancement of science and technology, various teaching methods have been adopted. For example, online educational platforms are utilized to share high-quality educational resources and make use of students' extracurricular time. These methods enhance classroom engagement, shift the traditional teacher-student dynamic by adopting a student-centered approach with teachers acting as facilitators, guide students toward self-directed learning, and strengthen interaction both between teachers and students and among students themselves[4].

1.3 Current Status of Laboratory Safety Education in the School of Chemistry and Materials Engineering at Anhui Science and Technology University

The laboratories at Anhui Science and Technology University have always prioritized safety education. Although our talent cultivation program has been continuously updated in response to national and societal needs, the fundamental importance of safety education has never changed. The safety-related courses offered by our school in recent years are listed in the table below:

Table 1: Safety-Related Courses Offered by the School of Chemistry and Materials Engineering in Recent Years

Major	Program	Course Name	Semester	Credit Hours (Theory+Experiment)
Materials Science and Engineering	2019 Program	College Student Safety Education	1	16
	2021 Program	College Student Safety Education	1	16
	2025 Program	Safety Education	1	24 (20+4)
New Energy Materials and Devices	2019 Program	College Student Safety Education	1	16
	2021 Program	College Student Safety Education	1	16
		Safety Production and Management (Required)	7	16
	2025 Program	Safety Education	1	24

				(20+4)
		Safety Production and Management	7	16
Inorganic Non-Metallic Materials Engineering	2019 Program	College Student Safety Education	1	16
		Safety Production and Management	7	16
	2021 Program	College Student Safety Education	1	16
		Safety Production and Management	7	16
	2025 Program	Safety Education	1	24 (20+4)
		Safety Production and Management	7	16
Applied Chemistry	2019 Program	College Student Safety Education	1	16
		Chemical Environmental Protection and Safety	5	16
	2021 Program	College Student Safety Education	1	16
		Chemical Environmental Protection and Safety	5	16
	2025 Program	Safety Education	1	24 (20+4)
		Chemical Laboratory Safety (Mandatory Elective)	1	16
		Chemical Environmental Protection and Safety (Mandatory Elective)	5	16
Smart Materials and Structures	2025 Program	Safety Education	1	24 (20+4)
Note: Our school offers the course Basic Chemistry Experiment for all majors in their first year, and the first class session covers content related to laboratory safety.				

Based on investigations, it has been found that safety education still emphasizes theory over practice; it has failed to tailor laboratory safety education to the specific needs of disciplines, experiment types, and students' majors and academic years. Furthermore, laboratory safety education has not been effectively integrated into the educational framework of "fostering virtue through education," resulting in a marginalized course positioning, a lack of comprehensive design throughout the entire academic cycle, and difficulties in quantifying and sustaining educational outcomes. Despite ongoing updates to the cultivation program, although the 2025 version incorporates safety education into the experimental teaching component, only the Applied Chemistry major offers a dedicated Chemical Laboratory Safety course. Additionally, while the university, school, and laboratories organize regular annual fire safety training and drills, these activities are predominantly demonstrative, with few hands-on practical laboratory safety education activities available for students.

In response to the existing problems and based on an analysis of the current hazard factors in the laboratory, it is necessary to establish and improve the laboratory safety education and access system, thereby achieving a dual enhancement of laboratory safety management and the safety awareness of both teachers and students.

2. Constructing a Safety Education System for University Chemistry Teaching Laboratories

2.1 Formulating an Implementation Plan Integrating Theoretical Safety Education, Practical Operations, and Awareness Campaigns Based on the "Three-Comprehensiveness" (All Personnel, All Aspects, Whole Process) Closed-Loop Safety Education Philosophy

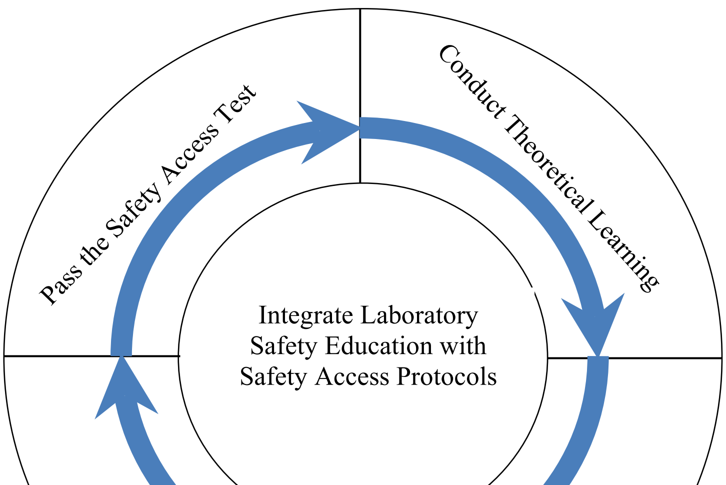

Figure 1: Laboratory Safety Education Implementation Plan Diagram

2.2 Main Components of Laboratory Safety Education Theory

Table 2: Suggested Teaching Content and Requirements for Laboratory Safety Education[5]

Course Chapter	Specific Learning Content	Teaching Requirements
Basic Safety Facilities in Chemical Laboratories	This includes recognizing common fire safety facilities such as manual alarm buttons, indoor fire hydrants, fire-resistant roller shutters, fire doors, evacuation exit signs, emergency lighting, safety exits and evacuation routes, outdoor fire hydrants, and various common fire extinguishing equipment. It also covers emergency eyewash stations, emergency showers, first-aid kits, and fume hoods.	a. Be able to explain the principles and functions of various safety facilities; b. Be able to correctly select and use relevant facilities to ensure the safety of oneself and others during experiments; c. Develop the habit of consciously observing safety facilities and exits upon entering a location, as well as an awareness of evacuation routes and precautions to be taken during an evacuation.
Safe Usage and Compliant Management of Hazardous Chemicals	Concepts and Hazard Classification of Hazardous Chemicals, Methods for Obtaining Chemical Safety Information, and Compliant and Legal Management of Controlled Chemicals.	a. Be able to understand the relevant regulations and standards for hazardous chemicals; b. Be capable of correctly identifying and using common hazardous chemicals in the laboratory; c. Be able to select appropriate accident prevention and emergency response methods for commonly encountered hazardous chemicals in the laboratory.
Fire Safety	a. Basic knowledge of combustion and explosion: conditions for combustion, types of combustion, combustion products and their hazards; definition of explosion, explosion limits, factors affecting explosion limits, and fundamental explosion protection measures. b. Characteristics and classification of fires, fire prevention and suppression, and escape and self-rescue procedures following a fire incident.	a. Be able to explain the conditions and types of combustion and explosion; b. Be capable of skillfully operating equipment such as dry powder and carbon dioxide fire extinguishers, as well as fire blankets; c. Be able to develop correct evacuation and self-rescue methods based on different fire scene situations.

Electrical Safety	Personal Safety, Electrical Circuit Safety, Electrical Equipment Safety, Main Factors Causing Electrical Fires	a. Be able to explain common knowledge of electrical safety; b. Be able to summarize the main factors that cause electrical fires, and describe the methods and principles for extinguishing electrical fires; c. Be able to describe how to administer first aid to a person after an electric shock occurs, and possess basic first aid capabilities for common electric shock accidents.
Pressure Vessel Safety	a. Definition and classification of pressure vessels, design requirements, and usage precautions; b. Basic knowledge of gas cylinders: classification, service life, stamped markings, color codes, filling and inspection, cylinder accessories and fittings, etc.; c. Safe usage rules for gas cylinders: storage, handling, and proper operation of gas cylinders.	a. Be able to identify common pressure vessels in the laboratory; b. Be able to explain the classification and service life of gas cylinders, recognize common color codes of gas cylinders and explain their inspection cycles, and identify and correctly use cylinder accessories and fittings; c. Be able to explain the requirements for storing and handling gas cylinders and perform these operations correctly; d. Be able to use gas cylinders safely; e. Be able to correctly handle gas leakage incidents involving cylinders.
Personal Protective Equipment	a. Eye Protection: safety glasses; protective goggles. b. Face Protection: protective face shields; face screens. c. Respiratory Protection: protective masks; half-mask respirators; full-face respirators. d. Hand Protection: chemical-resistant gloves; high-temperature resistant gloves. e. Body Protection: standard lab coats.	a. Be able to explain the most fundamental protection requirements in a chemical laboratory; b. Be able to elaborate on the various types of protective equipment commonly used in laboratories, and, based on the risk level, select and correctly use the appropriate protective gear; c. Be able to dress correctly in accordance with laboratory safety regulations.
Basic Safety Operating Procedures for Chemical Experiments	Safe use of reagents and glassware; preparation and safe handling of chromic acid cleaning solution; safe operation of alcohol burners for open-flame heating; safe use of infrared lamps, oil baths, reactors, centrifuges, high-temperature equipment, etc.	a. Be able to assess the potential safety risks associated with common chemical experimental operations; b. Be able to strictly adhere to operating procedures to ensure experimental safety.
Laboratory Hazardous Waste Disposal	Definition of Laboratory Hazardous Waste, Hazards of Hazardous Waste, and Classified Collection, Treatment, and Disposal of Laboratory Hazardous Waste	a. Be able to explain the potential hazards of hazardous waste; b. Be able to define and perform classified collection of laboratory hazardous waste; c. Be able to comply with environmental regulations by correctly storing laboratory hazardous waste temporarily to avoid causing pollution and harm.

At the undergraduate level, laboratory safety education can be fully integrated into learning stages such as basic chemistry experiments, core specialized experimental courses, undergraduate thesis design, as well as internships and practical training. Depending on the differences among majors, compulsory and elective safety education content should be selected accordingly.

2.3 Main Content and Forms of Practical Laboratory Safety Education

A year-round rolling safety training system should be established, incorporating diverse methods such as regular drills, VR training, hands-on practice, and online courses (e.g., small-scale micro-videos) to enhance students' practical operational skills.

a. Emergency drills are an important method in laboratory safety education and training. By simulating possible incidents within the laboratory, they allow students to personally experience and recognize potential dangers. These drills can strengthen communication and coordination among team members in the laboratory, clarify individual responsibilities, and foster a collaborative effort to jointly respond to various potential emergency situations. This intuitive educational approach is more effective than purely theoretical instruction.

b. The core content of VR training revolves around simulating real risk scenarios and conducting immersive practical drills. For instance, for the correct donning of personal protective equipment (e.g., protective clothing, goggles, gloves, respirators), the VR system uses motion recognition to assess the order of donning and the fit, triggering prompts for incorrect operations.

c. The core of hands-on practice is to translate theoretical standards into repeatable and verifiable practical skills, focusing on "correct operation." Examples include personally operating eyewash stations, emergency showers, and first-aid kits; immediately rinsing chemical burns with running water; and practicing "removing contaminated clothing followed by continuous rinsing."

d. Online education is not constrained by time or space. Requiring only an internet-connected device such as a computer or mobile phone, it enables learning anytime and anywhere, providing university students with more flexible and diverse learning methods. Students can be recommended to access high-quality courses from established universities, such as the "Chemical Experiment Safety Knowledge" Massive Open Online Course (MOOC) offered by the University of Science and Technology of China. This MOOC was approved as a National Top-Quality Online Open Course in 2018.

2.4 Forms of Laboratory Safety Education Promotion

Based on the content of laboratory safety education, various activities can be organized, such as safety knowledge contests, short video competitions on laboratory safety, publication of laboratory safety manuals, theatrical skits with laboratory safety themes during events, holding "Laboratory Safety Month," safety speech contests, and promoting exemplary deeds of teachers and students. These initiatives integrate safety education into campus life and the system of value identification.

2.5 Laboratory Safety Education Access

Differentiated access requirements are designed according to varying academic years, disciplines, and job responsibilities. A typical model is the "three-tier training" system: The first tier consists of orientation education for new students, focusing on imparting fundamental safety knowledge; after completing the theoretical component, students must pass a closed-book examination before they are permitted to learn in the laboratory. The second tier involves targeted training prior to specialized experimental courses, concentrating on practical skills such as instrument operation and chemical usage; students must demonstrate competence in standard operating procedures before entering the laboratory for learning. The third tier comprises specialized training for particular positions and high-risk experimental projects (e.g., in research laboratories), where individuals must pass a "pre-job assessment" before being allowed to operate. This system is supported by mechanisms that "integrate assessment with training" and "promote application through training." Specifically, through the approach of "theoretical learning + simulated drills + practical assessment," students develop a closed-loop growth in their capabilities during the progressively advancing learning process.

3. Conclusion

Perfecting safety education in university teaching laboratories is a complex and long-term systematic project that cannot be accomplished overnight. It must transcend the level of mere "management" and rise to the heights of "education" and "culture." Only by strengthening top-level design, constructing a scientific content system, innovating educational models, establishing long-term assessment mechanisms, and ultimately fostering a deeply ingrained safety culture can the principle of "Safety First, Prevention Foremost" be internalized as a conscious action by every teacher and student. Only in this way can we lay a solid safety foundation for the nation's scientific and technological innovation endeavors and truly achieve the sustainable development and long-term safety and stability of university laboratories.

Fund Projects

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