

# Developing a safety engineering experimental course using “Macro-Safety” discipline integration

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**Abstract.** Professional experiment courses are important to students’ understanding and recognition of professional knowledge as links to professional experiments. The University of Science and Technology Beijing’s “Macro-Safety” discipline integration approach to safety engineering was used to develop safety engineering experimental courses. Development methods were discussed. A research background in multiple dominant disciplines helped establish the cultivation mode for innovation in students majoring in safety engineering. We combined the traditional teaching mode with multi-disciplinary, innovative experimental teaching, which improved the students’ enthusiasm for studying safety engineering, enhanced their practicality and innovation, and laid a solid foundation for their comprehensive development. The research results of this paper can be used in metallurgy, materials, and other related majors.

**Keywords:** discipline integration; safety engineering; experimental teaching; curriculum construction

## 1. Introduction

In recent years, the university discipline of public safety has developed. The safety discipline is highly comprehensive and has a wide range of applications. It has mutual intersection, support, and promotion characteristics shared by other related disciplines. Based on the development status and layout of safety science and engineering disciplines, academicians Fan Weicheng and Yuan Liang proposed a safety science and engineering development goal for the “Macro-Safety pattern” of public safety during “the 14th Five-Year Plan” [1]. These goals were designed according to discipline development laws, trends and characteristics combined with China’s economic and social development needs in the next five years.

“Macro-Safety” is based on the basic theories and methods of safety discipline. It can be used to solve the safety problems faced by different industries and organizations and has broad adaptability. Presently, relevant universities with safety engineering specialties in China are attempting to integrate the concept of Macro-Safety into undergraduate and postgraduate education[2]. On 8 December 2020, the Research Institute of Macro-Safety Science of the University of Science and Technology Beijing was established. Based on the need for implementing a holistic approach to national security strategy, the University of Science and Technology Beijing (USTB) proposed the “one body and two wings” concept for developing the “Macro-Safety” discipline. This concept was based on the safety science and engineering of the National Center for Materials Service Safety and the National Metal Smelting Major Accident Prevention and Control Technology Support Base, which relied on “high-level, high-precision, advanced” construction projects of Safety Science and Engineering in Beijing. It would exploit the advantages of national first-class disciplines such as mining engineering, material science and engineering, metallurgical engineering, etc., to drive the development of emerging disciplines such as urban underground space safety, occupational health

and safety, public safety, and emergency management. It would strive to make safety a “national high-level, international first-class” and national high-grade, high-precision, and advanced discipline. The “Macro-Safety” view emphasizes the connotation and system structure of the safety discipline, improving the basic theoretical system, developing a wide range of professional objectives, and training comprehensive safety technology and management talents in large fields so that safety engineering can better contribute to the modernization of the national security system and its capabilities.

In this paper, we used the “Macro-Safety” view, based on the relevant basic theories of safety science, combined with the actual needs of undergraduate teaching in safety engineering specialties. We also integrate and discuss the characteristics of the University of Science and Technology Beijing’s dominant disciplines for developing experimental courses using “Macro-Safety” discipline integration. We proposed our development thoughts and implementation guarantees for these experimental safety courses.

## **2. Current major problems**

### **2.1 Single experimental teaching methods lack multi-disciplinary integration means**

With the Macro-Safety discipline system developing daily, safety engineering experimental courses are more significant since safety engineering is a discipline with high comprehensiveness, strong practicality, and wide, multi-disciplinary integration [3]. Based on the call for a more holistic view to national security, integrating safety engineering in experimental teaching for all fields of engineering meets the urgent need to combine various complex engineering problems such as resource development, metal smelting, material service, and urban underground space safety with safety engineering [4,5]. Despite the national and social demand for high-level safety engineering talents, safety engineering experimental courses only have single-teaching methods and less cross-disciplinary teaching content[6]. The traditional single-teaching method is usually based on a certain industry field. The general process is as follows: the primary experimental content is explained, and teachers demonstrate the simple experimental process. Then, the students repeat the experimental operation and complete the experimental report. The student’s ability to solve problems independently and design corresponding experimental schemes according to the problems has not improved in the traditional experimental teaching process. It does not meet the school’s training objectives for applied talents. In addition, traditional safety engineering experimental teaching focuses on the theory of the specialty. The experimental curriculum is biased towards the foundation, and relatively few experimental teachings intersect with other disciplines. Moreover, except for experimental instruments required for the class, students hardly have any other choices for instruments.

### **2.2 Lack of experiment funds and venues**

Safety engineering has a relatively short development time in many universities compared to many other disciplines. There is a certain gap in laboratory funds and equipment and a lack of effective and systematic experimental teaching instruments and equipment. Some colleges and universities have insufficient experimental sites. In addition to meeting undergraduate experimental teaching needs, the laboratory is also used for conducting scientific research experiments. The experimental equipment is placed in disorder; even if new experimental instruments are purchased, they cannot be placed[7]. At the same time, some experimental instruments used for undergraduate teaching have been idle for too long and unusable when needed. Students must resort to off-campus laboratories [8], which impacts students’ enthusiasm for professional learning.

### **2.3 Imperfect experimental outlines and textbooks**

Due to the specialty’s characteristics, safety accidents in different safety engineering industries are diverse and complex. Therefore, it is difficult to compile high-quality and representative

experimental outlines and textbooks. In addition, due to the relatively small amounts of students majoring in safety engineering, the audience of professional textbooks is relatively small, and the corresponding funds and energy invested by the school are inevitably insufficient, resulting in imperfect safety engineering experimental curriculums and textbooks.

### **3. The development of safety engineering experiment courses**

#### **3.1 Exploring the content boundaries of professional experiments using “Macro-Safety” multi-disciplinary integration**

Safety engineering is a typical interdisciplinary subject with professional comprehensiveness and high practical requirements. Experimental courses for undergraduates in the safety specialty should enable students to master the basic theories and laws of the specialty, understand and recognize the occurrence and development process of events, become familiar with detection and identification methods for different dangerous and harmful factors, understand technical methods and ways to realize intrinsic safety and obtain methods for conducting scientific research in the safety specialty. Experimental teaching in the safety specialty can help students to understand and master relevant theoretical knowledge, verify relevant laws of the safety specialty, and obtain better practical ability to solve problems. Therefore, professional experimental courses play a pivotal role in professional curriculum settings.

In line with the educational thoughts of “Macro-Safety” combined with the professional characteristics of USTB, when setting up specific experimental courses and safety projects, not only should the construction of experimental contents be conducted with the basic and professional courses of the specialty. At the same time, it is also necessary to highlight the development background for the mutual synergetic “Macro-Safety” discipline system of “resource development safety, metal smelting safety, occupational safety and health, material service safety, and urban underground space safety”[9], and focus on the practicality and intuition of experimental teaching to stimulate students’ creative thinking about multi-disciplinary integration. Professional experimental contents and USTB characteristics should be explored under the background of “Macro-Safety” multi-disciplinary integration. The experimental contents of resource development, metal smelting, material service, occupational health, and so on, must be increased to develop multi-disciplinary, innovative experimental courses based on safety principles so that students can better broaden their horizons, understand the safety needs of the dominant USTB disciplines, master safety-related theories and methods to solve safety problems in different industries, establish “Macro-Safety” academic thinking in the process of experimental learning, and improve the level of professional knowledge.

#### **3.2 Thoughts on safety engineering experimental course development under the background of “Macro-Safety”**

In line with the multi-disciplinary integration concept of “Macro-Safety”, when setting specific experimental items for safety engineering courses, not only should the experimental contents echo the corresponding basic and professional courses be considered, but also mining, metallurgy, materials and other majors of USTB. At the same time, the practicality and intuition of the experiment should be given full play to stimulate the students’ creative thinking. Therefore, the experimental items in safety engineering experiment of USTB are classified into four levels: general basic skill experiments, comprehensive professional verification experiments, characteristic professional research and exploration experiments, and virtual simulation experiments. The teaching objectives of experimental items at different levels are different as are the corresponding teaching methods and student requirements.

### **3.3 Improving teaching outlines and compiling experimental textbooks**

Experimental textbooks not only relate to experimental teaching and cultivating applied talents but also affect the development of scientific research. Experimental safety engineering textbooks affect safety professionals' training and application ability. They are the first step to initiating experimental teaching reforms under the "Macro-Safety" system, formulating reasonable experimental plans and contents, and compiling reasonable experimental textbooks. In this regard, teachers specializing in safety, mining, metallurgy, material service, and underground spaces discuss and improve the teaching outlines of the experimental course system, compile experimental textbooks, and organize teachers of relevant disciplines to evaluate the newly compiled experimental textbooks. The textbooks are submitted to several relevant experts for review and revision to ensure quality.

### **3.4 Strengthening the combination of experimental teaching and scientific research**

In order for students to access new safety technologies and achievements and broaden their horizons, they are encouraged to use professional instruments and equipment by applying for scientific research projects or participating in teachers' projects. Among them, the annual innovation and entrepreneurship training for undergraduates is a good opportunity for students to participate in scientific research. Using the professional theoretical knowledge they learned by consulting relevant references and peer discussion, students can determine experimental schemes, implement them to master the concepts of specific experiments, improve their ability to analyze problems, and conduct scientific research. These courses not only improve students' abilities but also the utilization rate of experimental equipment.

Students are encouraged to participate in various safety discipline competitions such as the "National University Safety Science and Engineering Undergraduates' Practice and Innovation Works Competition" held by the National University Safety Science and Engineering Academic Annual Meeting. These activities can improve students' innovation consciousness. Laboratory resources can be fully utilized at the same time. They also conform to the current talent cultivation program oriented by "application innovation".

### **3.5 Implementing open-laboratory teaching**

The safety engineering laboratory is the main innovation unit and an important carrier of the professional knowledge system[10]. Open-laboratory experimental teaching means that students can use their spare time to practice experimental content they are interested in. The existing experimental conditions are integrated with "Macro-Safety" in the National Center for Material Service Safety, the Key Laboratory for Dust Hazard Engineering Protection of the National Health Commission, the Key Laboratory of Ministry of Education for Efficient Mining and Safety of Metal Mines, the Beijing Key Laboratory of Urban Underground Space Engineering, and the Mine Risk Avoidance Technology Research Center, which are open to students in an orderly manner. After completing the compulsory experimental courses, students can select topics and design scientific and technological innovation experiments related to other relevant topics or the instructors' innovation projects. At the same time, students are encouraged to apply for and participate in experimental projects, including research, comprehensive and design experiments, models, invention and production experiments, subject competition experiments, etc. The teachers provide comprehensive guidance to students on laboratory opening, referencing experimental data, and answering experimental questions, thereby creating a research-based learning environment.

## **4. Achievements**

### **4.1 A high-level scientific research team of teachers was established**

Establishing a good scientific research team is important for improving the teaching level. The research team comprises teachers from the College of Civil and Resource Engineering, the College of Metallurgy and Ecological Engineering, and the National Center for Material Service Safety of the University of Science and Technology, Beijing, and meet the needs of the project for safety, mining, metallurgy, material services, and other specialties. This team can also strengthen specialty integration and create conditions for developing safety engineering experimental courses using “Macro-Safety” discipline integration.

The teaching team has rich experience, published many teaching and research papers, completed research in four school-level general teaching and research projects, and two school-level key teaching and research task groups, namely, the 1 + X mode of undergraduate cognition practice of safety engineering, and safety engineering practice base construction based on the safety training demonstration center of the China-Australia colliery. These works have laid a solid foundation for the research in this project.

### **4.2 Exploration of a good teaching management mechanism**

Managing the experimental platform is the core of developing experimental courses. In exploring the course development, experimental conditions from the relevant key laboratories were integrated at the national, provincial, and ministerial levels. Two professors, two senior engineers, an engineer, a lecturer, and a post-doctorate were equipped with strict and standardized laboratory management mechanisms. The teacher shift mechanisms were established to ensure that students receive sufficient resources and guidance in terms of the software and hardware conditions of the laboratory.

### **4.3 The “Macro-Safety” experimental teaching curriculum system was established with USTB characteristics**

Safety in the University of Science and Technology Beijing is a national key discipline and a high-grade, high-precision, and advanced discipline in Beijing. The safety engineering specialty of USTB is a national first-class undergraduate specialty construction point in Beijing. It has proficiency in the fields of ventilation, dust and poison prevention, emergency rescue, mine safety, engineering blasting safety, product safety, safety science, and management. Its undergraduate teaching system focuses on the characteristics of mine safety and other safety technologies. Experimental courses combine the mining, metallurgy, material services, and other USTB specialties, exploiting the resources in the university, strengthening the integration of specialties, and establishing a “Macro-Safety” experimental teaching course system with USTB characteristics.

### **4.4 Multiple disciplines were integrated organically into safety engineering experiment course**

Safety engineering experimental courses were developed according to the cultivation plan and relied on various professionals from USTB. and teachers from the College of Civil and Resource Engineering, the College of Metallurgy and Ecological Engineering, and the National Center for Material Service Safety. In order to ensure the basic training goals of “Macro-Safety”, the experimental courses are fully integrated with multiple disciplines. Exploration has already progressed on developing safety engineering experimental courses using “Macro-Safety” discipline integration[11].

### **4.5 An experimental teaching mode was developed**

In order to ensure the setting of general-purpose experiments, experimental teaching emphasis was placed on increasing comprehensive and characteristic professional research and exploration experiments. This step helps fully mobilize students’ initiative and enthusiasm, allowing them to

participate in the experimental preparation, design, operation, and analysis process and cultivate independent experimentation. New experimental outlines and textbooks have been compiled to improve education quality and teaching levels. Teachers' scientific research achievements have been integrated into experimental teaching so students can fully understand the frontier progress of the discipline and master advanced professional knowledge. The open-laboratory teaching mode was implemented to provide students with superior experimental conditions and encourage innovation.

## 5. Conclusion

In “Macro-Safety” discipline integration, cultivating high-level, application-oriented talents is now the goal of the safety engineering specialty. Therefore, exploring the development of safety engineering experimental courses is very important. Methods must be adopted, including general, comprehensive, and exploration experiments and characteristic specialty research integrated with teachers' scientific research achievements, improved teaching outlines, and experimental textbooks for developing safety engineering experiment courses. These measures will help improve students' innovation consciousness while ensuring their basic experimental operation level.

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