

# ***Practice of Experiment Teaching System for Basic Mechanics in Multi-Disciplinary Environment***

**Wei ZHAO**

*Key Laboratory of Disaster Forecast and Control in Engineering, Ministry of Education of China,  
Jinan University, Guangzhou 510632, China*

*tzhaowei@jnu.edu.cn*

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**Abstract:** The experimental course of basic mechanics is the foundation of multi-disciplines. Under the new situation of improving the teaching level with the goal of building a high-level university, training excellent engineers and excellent structural engineers, the existing teaching system of basic mechanics experiment cannot support the realization of these goals well. This paper explores several principles, practical measures and assessment index system on how to design and organize the multidisciplinary teaching system of basic mechanics experiment, so that students can analyze and solve problems more actively and deepen their understanding of professional knowledge when learning the multi-disciplinary experimental course. Literature review and extended project experiments are employed to cultivate their logical, critical and innovative thinking, thus improve their comprehensive applicable ability of professional knowledge.

## **1. Introduction**

Under the new situation, undergraduate education is increasingly required to develop a modular and multi-level experimental teaching system from foundation to synthesis, from theory to application and innovation <sup>[1-3]</sup>. Basic mechanics forms the basis of multi-disciplines, and experiment is an important part of building a perfect teaching system of basic mechanics, which not only enables students to better understand the frontier dynamics of basic mechanics in multi-disciplines, but also promote and improve their interest in learning with an independent exploration spirit <sup>[4]</sup>. Experimental teaching has really become an important part and necessary means to cultivate students' experimental skills and innovative ability, and then achieve the goal of improving students' comprehensive quality and innovation ability in scientific research <sup>[6]</sup>. But in most colleges, the limited teaching hours of basic mechanics experiment results in a fragmented system. For instance, there is a lack of vibration mechanics experiments, lack of experimental teaching equipment reflecting the new experimental methods or means, no close link between theoretical teaching and experimental teaching, the new theory and technology has not been covered in the existing experiment content, and etc. It is not beneficial to building students' complete system of disciplinary knowledge, the cultivation of their ability to use knowledge and engineering practice, and developing logical, critical and innovative thinking.

## 2. Experimental Teaching Status of Basic Mechanics in Multi-Disciplines

Typically, the basic mechanics experimental courses in material mechanics, engineering mechanics and experimental mechanics, involve majors of engineering mechanics, civil engineering, environmental engineering and environmental science in Jinan University where the authors work, with a wide range of interdisciplinary characteristics. Before the teaching reform mentioned in this article, the experimental equipment or devices mainly covered the basic experiments specified in the syllabus, including tension and compression experiments, torsion and shear experiments of typical materials, and etc. Despite the abundance of experimental teaching resources, on the one hand, the resource potential has not continued to be tapped and play a greater role in the cultivation of students' comprehensive quality and innovation ability. On the other hand, it cannot embody distinctive professional characteristics with a close integration with some teaching contents in multidiscipline, such as some courses, steel structure, building structure test, structural mechanics in civil engineering, and fluid mechanics in environmental engineering. Most of the experimental projects are confirmatory and demonstrative experiments in the past. There are few extended experimental projects for students to systematically summarize laws, independently design and implement in an open environment. The national schooling thought of developing "new engineering" puts forward higher requirements for students' practical ability. Consolidating the basic theory, deepening understanding the theoretical application boundary and strengthening experimental skills are the premise and foundation of improving practical ability, which should run through the whole experimental class. Confirmatory and demonstrative experiments can obviously not meet the above requirements. The understanding of basic theory often needs to be established through a series of experiments at different levels. Students' differences in different majors, between individuals and the other factors also urgently need deeper experimental projects to establish their professional self-identity, stimulate students' professional interest and develop a realistic, pragmatic and innovative work style.

## 3. Design and Organization of Experimental Teaching System for Basic Mechanics in Multiple Disciplines

It is an urgent need to reform the experimental teaching system of basic mechanics to configure multi-functional, multi-level and convenient experimental equipment or devices for multi-disciplines and open experimental projects. According to the professional characteristics respectively in major of civil engineering and engineering mechanics, this paper takes the establishment of basic mechanics experimental teaching system in multi-disciplines as the goal of teaching reform, and makes a preliminary attempt, achieving certain results. On the one hand, from the perspective of enriching experimental resources, the open experimental platform of material mechanics and vibration mechanics is established to provide basic material conditions for students to carry out more extensive and in-depth experiments. On the other hand, the experimental teaching activities are redesigned and organized according to new ideas.

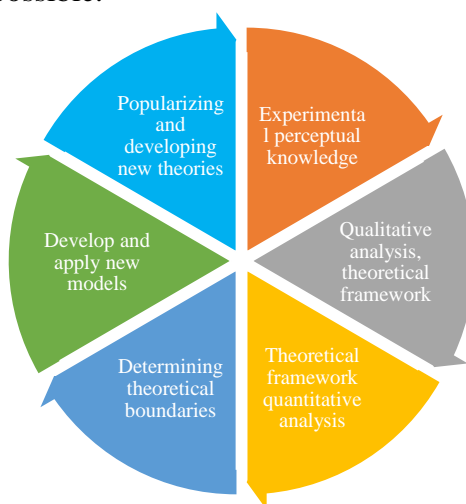
### 3.1 Basic Principles to Be Followed in the Design of Experimental Teaching System for Basic Mechanics in Multi-Disciplines

#### 3.1.1 Setting of Experimental Projects

(1) The principles of multidisciplinary fusion and systematization: In this paper, exploring experimental teaching system of basic mechanics in a multidisciplinary fusion is to establish a better experimental teaching system of material mechanics and vibration mechanics. Curriculum

system construction should be systematic, needs to consider the development order of curriculum system. The experimental projects that are required to be completed in different courses about bars, beams, single degree of freedom system and multiple degrees of freedom system should be comprehensively considered.

(2) The principle of multiple levels: Considering the differences of students' starting point, ability and the final requirements, each experiment is designed as far as possible following six levels, which in turn include perceptual knowledge and qualitative analysis of the experiment, establishing the theoretical framework and its quantization, identifying the boundary conditions, developing and applying the new model, promoting and developing a new theory. The six levels form a closed loop, and deepen iteratively (Figure 1). The experimental principle should be closely integrated with the theory, reflecting different levels of the theory. The experimental data should be linear and repeatable, and the experimental model should be designed as modular and combined as possible. This requires that the experimental model should have both ideal model and engineering model, scientific research model, to be able to guide each simple experiment to the level of experimental research as far as possible.



*Fig.1 The Multi-Level Design of Experimental Project*

(3) The principles of openness, extensible modularity: Open experiment projects are following as far as possible the idea of modular design, facilitating the experimental function expansion, keeping enough space of imagination and creativity for students, laying a solid material foundation for them from understanding and application to innovation.

(4) The principle of resource sharing: different types of experimental devices with the same function are installed in the same scheme or in an interchangeable way. It is convenient to share resources with manufacturers and sibling universities, and implement online and offline teaching, especially share experimental teaching and virtual simulation resources.

### **3.1.2 Design and Organization of Teaching Activities**

(1) The principles of the online and offline: In a teaching pattern of multidisciplinary fusion, the contradiction between less teaching hours and more content from different disciplines stands out. On the one hand, we will further improve the teaching resources system of basic mechanics experiment, including increasing and optimizing the experimental projects, writing and improving the experimental textbook so as to get closer to and meet the goals of interdisciplinary professional training, be convenient for online and offline teaching as an integrated system. The complementary online and offline teaching platform is constructed on the mature Internet platform, especially

making full use of QQ group, official accounts of Wechat, RainClass, MOOCs and other platforms to push the content that is not easy to expand in class to students in the form of articles, micro videos, so as to supplement the classroom teaching and effectively improve the teaching effect.

(2) The principle of flexibility and openness: Multimedia, virtual simulation and other teaching methods are flexibly used to intuitively display the mechanics principles, mechanical phenomena or mechanical laws. For certain engineering problems in multi-disciplines, open or expanded experimental projects are set up, and students are guided to explore experimental principles, design experimental schemes, verify experimental principles, analyze and discuss them with critical and creative thinking in teamwork. The experimental results and conclusions promote the cultivation of students' rigorous thinking and professional communication skills in the way of multimedia presentation and written report. Thus, the organic integration of individual learning and collective learning, classroom discussion and extracurricular learning, is realized, forming a span of interactive learning atmosphere, and stimulating students' enthusiasm and interest in professional learning.

### 3.2 Reform and Practice on Experimental Teaching System of Basic Mechanics in Multi-Disciplines

As an illustration, the following presents the design and practice on experimental teaching system of material mechanics in line with the above-mentioned principles.

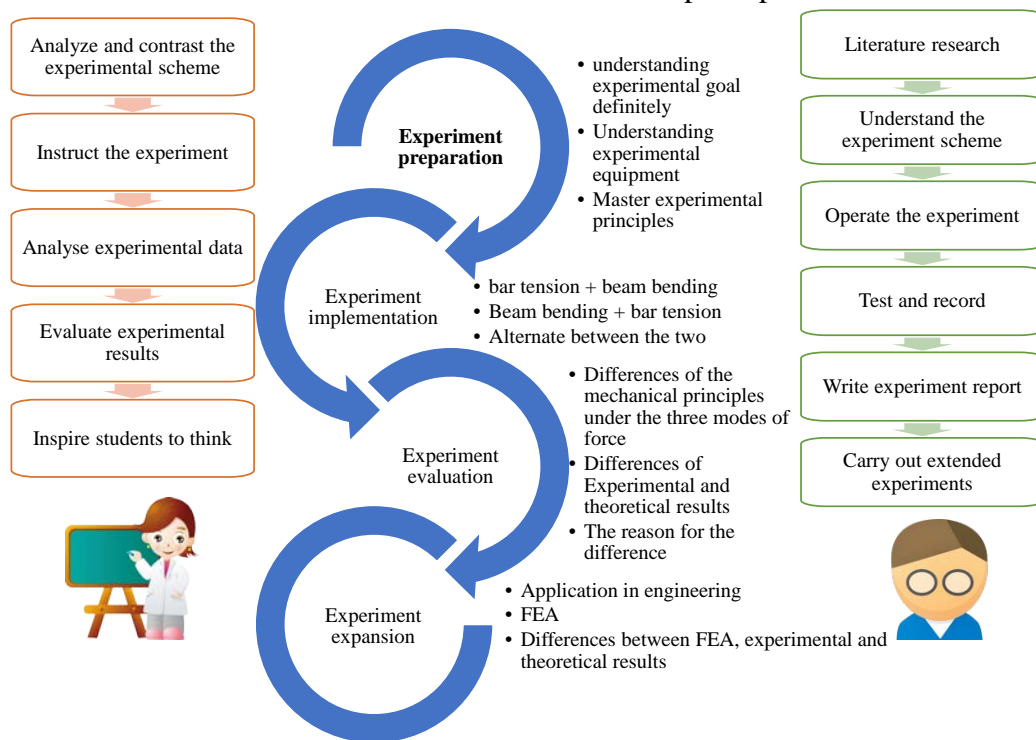


Fig.2 Design and Organization of Open Experimental Teaching Activities in Multi-Disciplines

Before the reform of experimental teaching system, the goals of material mechanics experiment mainly focus three aspects: stress distribution (how internal forces balance external forces), component deformation and strength failure. The main experiments include: tensile and compression experiments of typical metal plastic or brittle materials (low carbon steel, cast iron), experiment to determine the elastic modulus and Poisson's ratio of a material, measurement experiment on shear elastic modulus of a metal material, experiment on normal stress distribution of

pure bending beam, experiments on uniform intensity cantilever and Wheatstone bridge modes, experiment on distribution law of normal stress in pure bending of composite beam and laminated beam, experiments on deformation and strain measurement of a thin-walled circular tube under combination of bending and torsion, column stability experiment, comprehensive experiment on deformation law of a small rigid frame, demonstration experiment on dynamic strain test and impact.

The experimental projects and equipment could meet the basic experimental skills training (mainly electrical measuring method of strain, material mechanics performance tested by universal material testing machine), the interpretation of the experimental principle, hereto principle of mechanics of materials. Unfortunately, they are only confined to simple stress distribution and deformation of components commonly with a fixed mode. No extension or investigative experiments are presented, lacking flexibility in teaching. Complex stress distribution and slightly complex engineering application structure cannot be fully demonstrated in teaching, which is not conducive to students' further thinking and exploration.

Figure 2 shows the schematic diagram of design and organization of the open experimental teaching activities in multi-disciplines, as well as the specific design and organization of teaching activities of a small frame comprehensive experiment as an example. Specifically, open experiment teaching activities in multi-disciplines closely center around four aspects: experiment preparation, experiment implementation, experiment evaluation and expansion. From the perspective of students, teaching activities are divided into literature research, understanding the experiment scheme, operating an experiment, data testing and recording, writing reports, expanding experiments, a total of 6 stages. From the perspective of teachers, teaching activities can be divided into five stages: analyzing and contrasting experimental schemas, instructing experiments, analyzing experimental statistics, evaluating experimental results, and inspiring students to think. The interaction between the teachers and students, especially communication and discussion in the classroom and extracurricular online, attains the goal of cultivating and training students' common scientific literacy. Individual and collective learning, classroom, extra-curricular organic combination of online learning and discussion, form an investigative and interactive learning atmosphere, training students' critical and creative thinking in the process. A typical comprehensive experiment, such as small rigid frame, students are required to examine some issues before the experiment: how to choose bridge approach in electrical measuring method, what is the mechanical model of the small rigid frame and what is its practical significance in engineering. Afterwards, in virtue of literature research, mechanics model should be established to explain how the loading mode influences the strength of the small rigid frame, and guide how to apply in the practical engineering. In class, the teacher analyses and compares the experimental schemes under three different loading paths. After the experiment, according to the students' test data, the teacher analyses the experimental data under different loading path to further verify mechanical behavior characteristics of the small rigid frame, inspires students to think how the small rigid frame should be correctly installed in engineering practice, guides them to carry out expansion experiment, for example, performing numerical calculation in virtue of finite element analysis or other structural analysis software, comparing the numerical calculation results, theoretical results and experimental results to analyze differences between them. By means of these activities, students are trained to obtain the abilities in literature reading, report writing, question raising, problem analysis and solving problems by comprehensively applying the knowledge of various subjects, so as to develop good scientific literacy.

#### **4. Implementation of Experimental Teaching System for Basic Mechanics in Multi-Disciplines and Its Assessment Indicators**

In the experimental teaching system for basic mechanics in multiple disciplines, the following problems should be considered in practice: the mutual connection between different disciplines in the teaching schedule should ensure that students have the prerequisite for the integration of basic knowledge of the subject. Those teachers preparing experiments should strengthen communication with teachers from the integrated subjects. If necessary, teachers from the integrated subjects are allowed to participate in experiment teaching, so as to ensure the accuracy and professionalism of integrated subjects knowledge. Students can be guided to select topics for college students' innovation and entrepreneurship projects on the basis of interdisciplinary crossover and integration, so as to further improve students' ability to comprehensively utilize knowledge. Evaluation on experiment teaching system for basic mechanics in multi-disciplines should pay more attention on the application and development of subject knowledge. Table 1 lists two-level index system to evaluate the experiment teaching system for basic mechanics in multi-disciplines. On the basis of the traditional teaching pattern, literature research and experiment expansion are additionally examined, on the one hand to strengthen students' comprehensive and profound understanding about the integrated disciplines, lay the foundation for comprehensive experiment, on the other hand, to evaluate the leaning effect in expansion experiments. Therefore, the weight of this part could be appropriately increased in the evaluation of students' comprehensive performance.

*Table 1 Indices to Evaluate the Experiment Teaching System*

First level indicator	Second level indicator
Literature research	(1) Integrity (2) Accuracy (3) Advancing
Experiment scheme	(1) Rationality (2) Logicality
Experiment operation	(1) Proficiency (2) Technical difficulty (3) Team Cooperation
Data testing and recording	(1) Accuracy (2) Scientificity (3) Completeness
Experiment report	(1) Structural rationality (2) Analytical logicality (3) Writing norms
Extensibility experiment	(1) Innovation of experimental scheme (2) Quality of experiment report

## 5. Conclusions

As an important basic course for engineering majors, basic mechanics experiment plays an important role in cultivating students' practical ability, logical thinking, critical thinking and even innovative thinking. Especially under the new situation of continuously improving the teaching level with the goal of building a high-level university, training excellent engineers and excellent structural engineers, the existing teaching system of basic mechanics experiment has been unable to support the realization of these goals. This paper analyses the present situation of the teaching mode of basic mechanics experiment in multi-disciplines, discusses several principles, concrete practice and assessment index system of design and organization of the teaching system for basic mechanics experiment in multi-disciplines, and puts them into practice in teaching. From the effect of implementation, it has been widely welcomed by students, which has improved their enthusiasm and interest in the major, deepened their understanding of the laws of mechanics, and made them realize that mechanics is no longer just a boring theory and formula, but has a wide range of engineering applications and values within reach. However, due to the complexity of basic mechanics experimental teaching in multi-disciplines, long-term practice, and rapid application of specialized knowledge, the proposed teaching model for basic mechanics experiment in multi-disciplines needs to be tested for a longer time, and its effectiveness needs more empirical research or even continuous improvement and development in the future.

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