Reform of the Experimental Teaching Mode of the Course "Sensor and Detection Technology" Under the Background of Engineering Education

Ziwen Song[1a], Xiuting Shao[1*b] Hengbiao Chen[1c], Mengjiao Lu[1d]

[a] Sonorouszw@163.com, [b] shaoxiuting@126.com*, [c] stcnsuy@163.com, [d] lu_mengj@163.com

[1]School of Information Science and Engineering, Shandong Normal University, Jinan, Jinan250358, China

Abstract. Experimental teaching is one of the key contents of engineering education and it is also a powerful means to cultivate the research quality of undergraduate students. It enables students to gradually learn and master the ability to solve complex engineering problems, thereby meeting the requirements of engineering education. This paper analyzes the current situation and existing problems of experimental teaching in the "Sensor and Detection Technology" course. Combining with the concept of engineering education, this paper proposes the direction of reform and innovation form the aspects of improving teaching mode, enriching experimental content, optimizing teaching methods, and forms an effective mechanism for continuous improvement.

Keywords: Experimental teaching; Engineering education; Educational reform; Sensors course.

1 INTRODUCTION

With the continuous development of modern technology, various types of sensors have been widely used in people's daily life. As one of the three pillars of the new generation of information technology[1], sensor technology is a high-tech industry that is currently being developed by various countries, as shown in **Fig. 1**. From a macro perspective, the development of the sensor technology industry plays a very important role in improving international competitiveness[2]. "Made in China 2025", issued by the State Council, points out that it is necessary to accelerate the development of the Chinese sensor and IoT industry towards integration, innovation, ecology, and clustering[3].

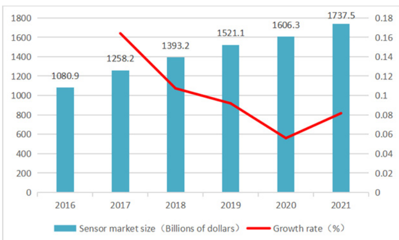

Fig. 1. Market Size and Growth Rate of the Sensor Industry Worldwide from 2016 to 2021 (Unit: USD Billion)

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The "Sensor and Detection Technology" is a core course of automation, measurement and control instruments, electronic information and other majors in universities, in which experimental teaching is an important part of the course teaching process. Typical experiments as shown in **Table 1**:

Table 1. Curriculum Typical Experiment

Sensor Type	Experimental Content
Force-sensitive sensors	Measure output signals under different forces
Gas-sensitive sensor	Measure output signals under different gas concentrations
Humidity-sensitive sensors	Measure output signals under different humidity levels
Capacitive sensors	Measure output signals under different capacitance levels
Inductive sensors	Measure output signals under different inductance levels

However, at present, there are some common problems in the experimental teaching of sensors, such as outdated teaching models, limited and theoretical experimental content, outdated teaching methods. These issues are not in line with the concept of cultivating innovative talents in the field of sensor technology. Therefore, it is urgent to reform the experimental teaching mode of the sensor course by using the concept of engineering education and scientific methods.

2 Reforming the Experimental Teaching Mode

To address the prominent issues in experimental teaching, we propose a reform of the teaching mode, which focuses on improving experimental teaching content.

The reform of experimental teaching content is divided into four parts: the basic experiments, the comprehensive experiments, the design experiments[4], and ideological and political education, as shown in **Fig. 2**.

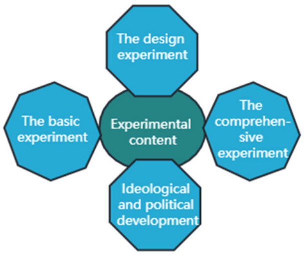

Fig. 2. Elements of Experimental Teaching Content Reform

2.1 The Basic Experiment

According to the requirements of engineering education, the experimental teaching content for "Sensor and Detection Technology" will be student-centered, and the teaching content will be hierarchical taking into account their learning characteristics [5]. This approach aims to help students better understand and grasp the content of the experiment, the basic experiment is set as the first step.

The "Sensor and Detection Technology" course includes several basic experiments. Taking the semiconductor gas sensor experiment (alcohol) as an example, the basic experiment is performed according to the steps listed in **Table 2**.

Table 2. Basic Experimental Procedure of Alcohol Sensor

Experimental stage	Experimental purpose	The main learning content
Phase I	Clear experimental objective.	To understand the principles and applications of gas sensors.
Phase II	Familiar with experimental instruments.	Gas sensor, alcohol, cotton ball (self-provided), differential transformer experiment module.
Phase III	Clear experimental principle.	The oxidation and reduction reactions of gases on the semiconductor surface lead to changes in the resistance of the sensor.
Phase IV	Familiar with experimental contents and procedures.	Operating testbed.

2.2 The Comprehensive Experiment

Comprehensive experiments refer to composite experiments[6] that integrate the knowledge of several courses and provide comprehensive training for students' experimental skills and methods based on their foundation of basic knowledge and operational skills. For example, a comprehensive experiment can be designed by combining courses on sensors, signal acquisition, data processing, and simulation experiments [7]. In the alcohol sensor comprehensive experiment, students are required to complete the following tasks:

(1) Set up experimental platform: Build a sensing test circuit according to requirements and standardize operations to obtain accurate measurement data while ensuring safety as shown in **Fig. 3**.

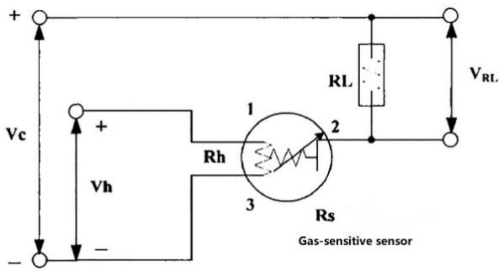

Fig. 3. Circuit Diagram for Sensor Testing [8]

(2)Signal acquisition: Clarify the signal transmission type in the experiment, observe and record various signal changes. In this experiment, the input signal is alcohol gas, represented by gas concentration, while the output signal is the change in conductivity of the semiconductor caused by the reaction between alcohol and the semiconductor, represented by the change in resistance or voltage.

(3) Simulation and processing: The measured data obtained from the experiment are input into MATLAB software for system and algorithm modeling and simulation to evaluate the control effect of the system [9]. The generated charts and graphs are useful for summarizing knowledge and identifying patterns. For instance, as shown in **Fig. 4**, the curve graph generated from the experimental data of the relationship between alcohol gas concentration and voltage indicates a positive correlation between alcohol concentration and voltage magnitude.

Alcohol concentration/%	Vo(the first time)/V	Vo(the second time)/V	Vo(the third time)/V	Vo(the fourth time)/V	Vo(the fifth time)/V	Vo(the sixth time)/V
10	0.952	1.087	1.105	0.998	1.004	1.029
20	1.370	1.389	1.395	1.381	1.358	1.379
30	1.784	1.832	1.829	1.802	1.825	1.814
40	2.135	2.157	1.120	2.144	2.157	2.143
50	2.280	2.299	2.289	2.270	2.283	2.284
60	2.402	2.432	2.448	2.428	2.433	2.423
80	2.532	2.551	2.554	2.543	2.556	2.547
100	2.642	2.661	2.659	2.650	2.654	2.653

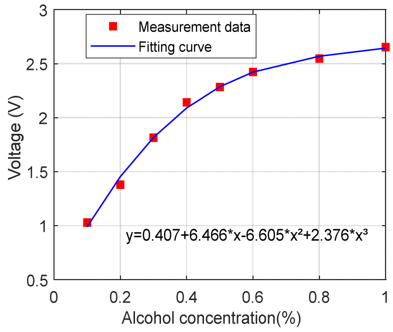

Fig. 4. Alcohol Gas Concentration vs Voltage Relationship Data and Curve[10]

(4) Validating the inference: taking semiconductor SnO2 as an example, the resistance value R and the mass fraction C of alcohol gas exhibit a logarithmic relationship.

$$lgR=-algC+b \tag{1}$$

Where a and b are constants representing the gas separation degree and gas detection sensitivity, respectively.

Based on Equation (1), we can infer the relationship between the concentration of alcohol gas and the resistance value of the SnO2 semiconductor:

$$R=10^b/C^a \tag{2}$$

According to equation (2), the concentration of the alcohol gas under test is inversely proportional to the semiconductor resistance R, as shown in **Fig. 5**. As the concentration of the alcohol gas increases, the semiconductor resistance decreases, causing an increase in voltage under stable current. Therefore, the verification is successful.

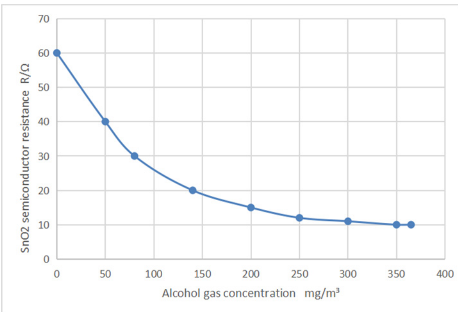

Fig. 5. Relationship between alcohol gas concentration and SnO2 semiconductor resistance

(5) After-class research: Students conduct after-class research on various sensors, evaluate the advantages and disadvantages of each type, and determine which sensor is more suitable for each specific experiment.

The reform of comprehensive experiments can help students overcome the barriers between different disciplines and develop their ability to apply knowledge in a comprehensive way.

2.3 The Design Experiment

After completing the foundational and comprehensive experiments, students move on to learn the sensor design experiment. [11]. These experiments allow students to give full play to their imagination and creativity and choose the direction, theme and title of the experiment independently.By combining their existing knowledge, students can provide complete solutions to practical problems in daily life.

Students can choose one of the given application scenarios, such as human joint posture detection and recognition, ceramic kiln temperature control, atmospheric pollution particulate detection, and smart restroom flushing system, and design a sensor system to achieve specific functions using the knowledge they have learned.

Taking the "Smart Toilet Flushing System" as an example, students can complete the design experiment by following steps:

(1) Experimental goal setting: Clarify that the project goal is to save water and maintain hygiene, therefore, it is necessary to develop a smart toilet flushing system that can automatically control the flushing amount and frequency based on usage and ensure that each flush could be cleaned effectively.

(2) Hardware design: Select appropriate hardware for the system, including sensors, actuators, and microcontrollers, as shown in **Fig. 6**.

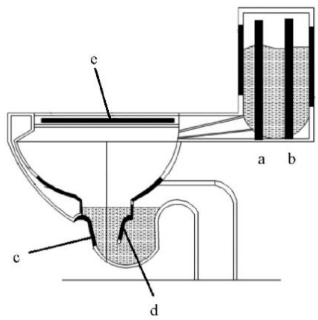

Fig. 6. Overall Structure of the Smart Toilet[12]

For example, use a capacitive sensor or pressure sensor to detect water flow and pressure and control the actuator (such as a solenoid valve) to adjust the flushing amount and frequency as needed.

(3) Software design: Choose a suitable programming language such as C to write software to implement the system's automatic control, the core code is shown in **Fig. 7** below.

```
while (cleanliness < 100 && !damaged && !repaired) {
    if (in_use) {
        if (water_level < 50) {
            printf("Water in the tank is insufficient, storing water...\n");
            water_level = 100;
        } else {
            printf("Water in the tank is sufficient, flushing toilet...\n");
            cleanliness += 20;
        }
    } else {
        printf("No one is using, please wait...\n");
    }
```

Fig. 7. Core Code 1

This section of code describes how the control system determines the timing for flushing and storing water. The cleanliness variable represents the cleanliness of the water, while the water_level variable represents the height of the water, which can be measured in real-time using sensors. If it is necessary to check whether a second flushing is required, refer to **Fig. 8**:

```
if (cleanliness < 100) {
    if (water_level < 50) {
        printf("Water in the tank is insufficient, storing water...\n");
        water_level = 100;
    } else {
        printf("Water in the tank is sufficient, flushing toilet...\n");
        cleanliness += 20;
    }
}
```

Fig. 8. Core Code 2

In the case of sufficient water volume, the cleanliness of the water is reevaluated to determine whether a second flushing is required. If the cleanliness of the water meets the requirements, the entire program process is completed.

The core of the design is to write an algorithm that can judge when to flush and how to control the flushing amount and frequency based on sensing data, the system flowchart is shown in **Fig. 9**.

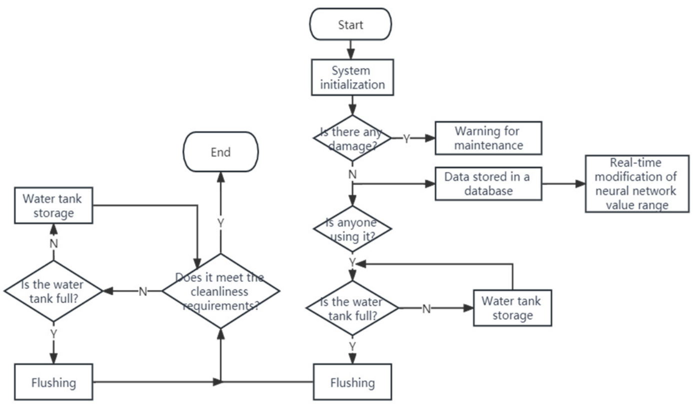

Fig. 9. Smart Toilet Flushing System Flowchart

(4) System testing: Use simulation tools and actual hardware to test the system to ensure the correctness and reliability of its functions. For example, use a capacitive sensor c and d to detect the cleanliness of the water to determine whether it is clean and whether a second flush is needed, as shown in **Fig. 10**.

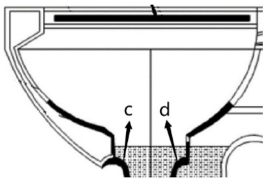

Fig. 10. Structure of Cleanliness Detection

(5) System optimization: Based on the test results, optimize the system to further improve its performance and reliability. For example, use electrode plates a and b to detect the water level in the tank to determine whether timely water storage is necessary, as shown in **Fig. 11**.

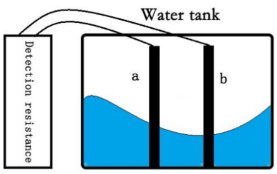

Fig. 11. Structure of Water Level Detection

By following these steps, students can gain a deeper understanding of how to break down tasks in order to complete projects and solve problems through practical experience. In addition, they can learn how to design and implement intelligent systems, as well as optimize their performance and reliability. This will enable them to better tackle future engineering challenges.

2.4 Strengthening Ideological and Political Education

On October 31, 2022, Chinese government issued the 'Notice on Deepening the Study, Propagation, and Implementation of the 19th National Congress of the Communist Party of China in the Education System' [13]. The 'Notice' emphasizes the need to vigorously promote the construction of new educational infrastructure, transform and innovate education models. The 'Notice' also requires the scientific and reasonable embedding of ideological and political elements into sensor experimental teaching.

For instance, when studying pressure sensors, we can present their critical application in automobile tires to reduce car accidents and guide students to think about the role of sensor technology in safeguarding human life and property security.

Integrating experimental sensor teaching with ideological and political education can facilitate students in comprehending the functions and significance of sensors, as well as enhancing their cultural awareness and sense of social responsibility.

3 CONCLUSIONS

Under the background and concept of engineering education, the current experimental teaching mode of courses urgently needs to be reformed. Through the analysis of the practical teaching of the "Sensor and Detection Technology" course, this paper proposes a reform scheme for the experimental teaching mode of the course, which has achieved good results in practice. The above reform can effectively improve the teaching efficiency of teachers, enhance the students' sense of participation, and enhance their autonomous learning ability and practical ability [14], highlighting the essence of the concept of engineering education.

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