Exploration of Teaching Methods for Sensor Principles in the Digital Background

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Abstract: With the transformation of the training methods for students majoring in measurement and control technology and instruments under the background of digitalization, new requirements have been put forward for the construction of core courses in this major. In this paper, based on the characteristics of the "Sensor Principles" course, the reform ideas of the sensor principles course in the context of digitalization is explored, and the establishment of a digital demonstration database of sensor principles for digital display of the sensor principle is introduced. This course presents the sensitive structure, sensing principle, and signal processing circuit of sensors in a digital way, intuitively and completely demonstrating the principles and parameter influence laws of sensors. It enables students to have a deep understanding of the working principle of sensors, improve their hands-on ability, apply what they have learned, and solve practical engineering problems.

Keywords: Digitization; Measurement and Control Technology and Instruments; Core Courses; Sensor Principle; Database

1. Introduction

Under the background of digitalization, the talent cultivation mode for the major of measurement and control technology and instrumentation is undergoing a transformation [1-4], and the course construction ideas of the core course "Sensor Principles" also need to be constantly adjusted to support the this major. Sensors are the source of information technology, the front-end of intelligent systems, and a comprehensive technology that encompasses multiple disciplines and technologies [5,6]. As the core course of undergraduate majors, "Sensor Principles" covers various types of sensors, including sensitive structures of sensors, physical quantity transfer relationships, signal processing, performance evaluation and applications, and more, and these contents include interdisciplinary and technological intersection of mathematics, physics, chemistry, biology, materials, machinery, electrical and electronic, microelectronics, control, computer, and more [7-10]. The course "Sensor Principles" has a weak system, lack of emphasis, and distinct uniqueness. The course content has a low learning threshold on the surface, and preliminary learning is relatively easy, while in-depth learning is difficult.

Due to the lack of intuitive understanding of sensors and limited exposure to practical engineering problems, students lack a deep understanding of the sensitive structural characteristics, working principles, and calibration processes for specific sensors. At the same time, existing sensor courses often have more structural schematic diagrams and few physical sample diagrams; more principle formula model derivation and less intuitive and vivid principle presentation; more textual process introduction and less demonstration of device operation. These problems have a significant impact on the teaching effectiveness of sensor principles and applications. The digital demonstration of course content, especially the digital demonstration of sensor principles, has significant demand and value in the construction of core course "Sensor Principles". This paper explores the teaching method of digital display of sensor working principles in the context of digitalization, based on the demand for course construction of "Sensor Principles". It aims to visually display the sensitive structure, sensing principles, and signal processing circuits of sensors, enabling students to deeply understand the working principles of sensors, enhance their hands-on ability to apply what they have learned, and solve practical engineering problems.

2. Difficulties and Analysis of Course Teaching

The course of "Sensor Principles" is the core course of Measurement and Control Technology and Instrument major. The course mainly focuses on teaching several types of sensors, including variable resistance sensors, thermoelectric sensors, capacitive sensors, piezoelectric sensors, electromagnetic sensors, resonant sensors, photoelectric sensors, and other main principle types of sensors, and specific sensors could be classified according to the measured physical quantity, including pressure sensors, temperature sensors, force sensors, mechanical displacement sensors, vibration sensors, angle sensors, and other types [5].

The course is aimed at these types of sensors, and the teaching content includes measurement mechanisms, physical quantity conversion, mechanism models and verification methods. Based on this, further analysis is conducted on the influencing parameters, parameter influence laws, and experimental verification of laws. The course involves interdisciplinary and technological fields such as mathematics, physics, chemistry, biomaterials and machinery, electrical and electronic engineering, microelectronics, control, and computer science. The course content is decomposed as shown in Figure 1.

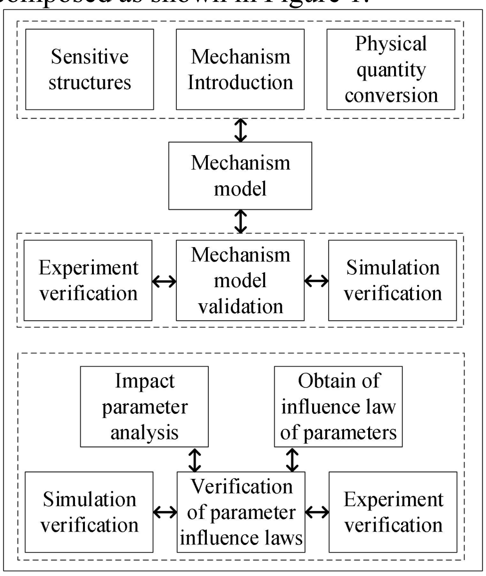

Figure 1. Course Content

For individual sensors and a type of sensor, the course content is systematic and continuous, but the course system is weak, the focus is not prominent, and the uniqueness is distinct. This course has a low learning threshold on the surface, and preliminary learning is relatively easy while in-depth learning is difficult.

Through the study of the course "Sensor Principles", the desired learning objectives are shown in Figure 2. For various types of sensors as learning objects, the course content is taught through classroom lectures, experiments, assignments, and tests. Through the above teaching methods, three levels of goals are set: learning sensor principles, learning problem analysis methods, and learning practical engineering problem-solving ideas.

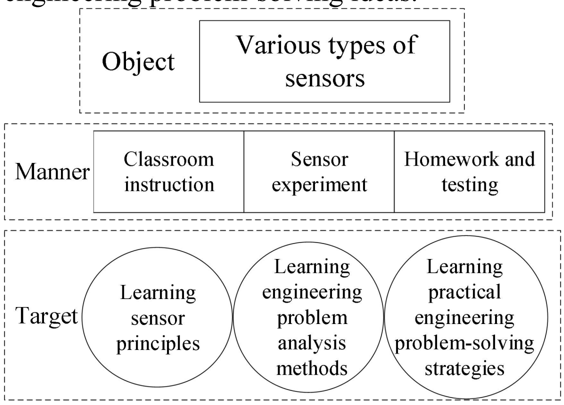

Figure 2. Objects, Means and Goals

The above characteristics of the sensor course content increase the difficulty of student learning and teacher teaching. At the same time, students lack intuitive understanding of sensors and have limited exposure to practical engineering problems, resulting in a lack of profound understanding of the sensitive structural characteristics and working principles of sensors. However, in existing sensor courses, there are more structural diagrams and fewer physical sample diagrams; multi principle formula model derivation and less intuitive and vivid principle presentation; more textual process introduction and less demonstration of device operation, and these problems affected the teaching effectiveness of sensor principles. This paper attempts to use the digital demonstration teaching method of sensor principles to solve the above problems. The research focus is on building a digital demonstration database of typical sensor principles, which involves the teaching content of typical sensor principles, students' understanding of typical sensor principles, and digital expression of typical sensor principles after learning and understanding them.

3. Teaching Method

Adapting to the trend of teaching reform in measurement and control courses under the background of digital education, this paper explores the digital demonstration teaching method of sensor principles from the perspectives of sensor principles and applications. The typical sensitive structure of sensors is designed and processed, and a digital demonstration database of sensing principles is established to fully display the characteristics of various physical quantity conversion links in the sensor's working process, as well as the structure, materials, and conversion circuits along the entire "information link", and match them with industry application requirements. The above process increases student participation and stimulates their enthusiasm for learning, which is conducive to their subjective formation of a courageous and positive academic philosophy to overcome difficulties. And teachers could also timely understand and grasp the real learning dynamics of students, so that students could avoid "principle errors" in the course learning process.

3.1 Digital Demonstration Database of Sensor Principle

Taking typical sensors as objects, students are guided to analyze the characteristics of sensitive structures and the conversion relationships of various physical quantities in the complete "information link" through methods such as split sensor physical samples and finite element simulation calculations, forming a physical understanding of sensor principles, and establishing a digital model of sensor principles. Combining specific structural size data, physical quantity conversion relationship models, and signal processing circuit parameters, a digital demonstration database of typical sensor principles is formed and used for digital display in the teaching process.

Taking a typical silicon piezoresistive pressure sensor as an example, the packaged sensor and pressure sensitive structure are shown in Figure 3. This pressure sensor adopts a two-stage pressure sensitivity, and the outer pressure diaphragm experiences elastic deformation after sensing pressure. The elastic deformation compresses the pressure conducting medium (usually silicone oil, etc.), guiding the external pressure to the pressure sensitive structure inside the sensor. The schematic diagram of the sensitive structure obtained by splitting, as well as the physical quantity conversion relationship, are shown in Figure 4 and Figure 5, respectively. Silicon piezoresistive pressure sensor is a typical pressure sensor, which is often used as a front-end device for pressure measurement in pressure instruments and measurement systems [11,12]. As shown in Figure 4, the pressure sensitive structure of the silicon piezoresistive pressure sensor is a silicon cup structure, and the silicon film at the bottom of the silicon cup is a pressure sensitive film.

Figure 3. Silicon Piezoresistive Pressure Sensors and Sensitive Structure

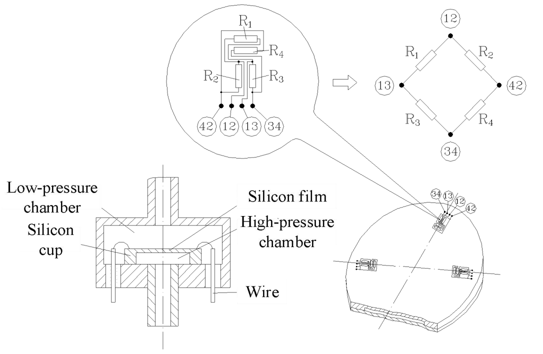

Figure 4. Schematic diagram of the sensitive structure

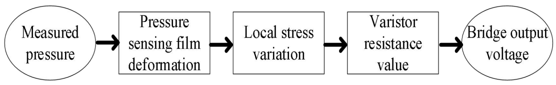

Figure 5. The Physical Quantity Conversion Relationship

Piezoresistive resistors are processed on the silicon film (usually made in pairs). When pressure acts on the module, it produces deflection deformation, and the stress in the area where the resistor is located changes. The resistor senses this stress and converts the change in stress into the change in resistance value of the resistor. By analyzing the mechanical properties of silicon films, it is possible to select the areas and quantities for making piezoresistive resistors, and accurately measure the changes in resistance by forming a bridge circuit with the resistors. Due to the definite relationship between the resistance value of the piezoresistive resistors and the stress at its location, which is determined by the uniformly distributed pressure loaded on the silicon film, the measured pressure value could be calculated based on the variation of the piezoresistive resistor.

A schematic diagram of the sensitive structure could be drawn for the physical sensor and the sensitive structure obtained through disassembly, the physical quantity conversion relationship could be analyzed, and a conversion relationship model could be established. Based on this, a sensor mechanism model could be established. Finite element simulation calculations could be used to validate the model, and the influencing parameters and their influence laws could also be analyzed and verified. Based on the above analysis process, a large amount of analytical data could be obtained, which could be used to establish a digital demonstration database of this type of sensor principle.

3.2 Digital Demonstration of Classroom Teaching

Classroom teaching is the main part of the "Sensor Principles" course, and the digital demonstration of sensor principles is the core of the method discussed in this paper. The digital demonstration database of sensors could be used to carry out classroom teaching and digital demonstrations, which enables students to have an intuitive, vivid, and complete understanding of the principles and calibration process, stimulate their interest in learning sensor principles, and actively think about corresponding teaching content. Through classroom discussions and homework assignments, teachers could timely obtain students' mastery of this part of the learning content, and make timely and accurate adjustments to the teaching content and methods.

3.3 Database Expansion and Enrichment

In addition to classroom demonstrations, attracting and guiding students to participate in the production of digital demonstration databases for typical sensors outside of class could increase student participation and stimulate their learning enthusiasm through the above process, which is conducive to their subjective formation of a brave and positive academic philosophy of overcoming difficulties.

This process is also a process for teachers to understand the teaching effectiveness of the digital demonstration teaching method of sensor principles, which could help teachers to timely understand and grasp the real learning dynamics of students, so that students could avoid "principle errors" in the course learning process, which enhances their hands-on ability to apply what they have learned and their ability to solve practical engineering problems.

4. Evaluation of Teaching Effectiveness

For the digital demonstration teaching method of sensor principles proposed in this paper, its teaching effectiveness needs to be evaluated in a timely manner, and the above methods need to be adjusted and improved based on the evaluation results to form a closed-loop continuous improvement. The evaluation of the teaching effectiveness of this digital demonstration teaching method of sensor principles could be designed at different teaching stages, and the evaluation method could be observed through different design indicators, such as personalized experience, proactively participation and Independent completion.

The following methods could be used to evaluate the digital demonstration teaching method of sensor principles.

4.1 Personalized Experience

In classroom teaching, through discussions and communication during the demonstration phase, timely understanding of students' experiences and feelings towards the digital demonstration content of typical sensors, timely understanding and mastering of students' real learning dynamics, could avoid "principle errors" in the course learning process. The personal experience of students in digital demonstration teaching content is an effective way to preliminarily evaluate the effectiveness of teaching. Based on the personal experience of students, teachers could also adjust the content, methods, and teaching process of digital demonstration, which provides a basis for the continuous improvement of the digital demonstration teaching method of sensor principles.

4.2 Proactively Participation

In classroom teaching, increasing student participation through specific content explanations and digital demonstrations, and observing student active participation during the classroom teaching process, as well as analysis methods and predicting results of sensor principle during discussions, to judge the status of student learning and the attractiveness of teaching methods. The enthusiasm of students and their way of thinking in participating in the digital demonstration process of the course to a certain extent reflects their understanding of the learning content, especially their understanding of the digital demonstration part of the content. This is also a reflection of teaching effectiveness for the digital demonstration teaching method of sensor principles. Therefore, evaluating this teaching method through participation could also provide specific ideas and ways to improve the digital demonstration teaching method of sensor principles.

4.3 Independent Completion

After experiencing the digital demonstration process of a type of sensor principle, students could draw inferences and analyze the principles of other types of sensors in the same way. And by comparing the analysis process completed independently with the analysis process provided by the course, students could evaluate the learning effectiveness. This process is both a learning process and a self-examination of learning effectiveness.

At the same time, this process could also attract students to participate in the production of the typical sensor digital demonstration database, analyze and study the principles of different types of sensors, and increase their participation through the above process, stimulate their learning enthusiasm and forming a brave and positive academic philosophy to overcome difficulties.

Through the evaluation of this digital demonstration teaching method of sensor principles at different teaching stages mentioned above, the teaching effectiveness of the digital demonstration teaching method for sensor principles could be preliminarily judged, in order to adjust and improve this teaching method in a timely manner. At the same time, students could analyze the same content on their own through the entire process of learning sensor principles, and compare it with the course explanation process to determine the achievement of their own learning goals, and discuss with the teacher.

5. Summary

In order to meet the talent cultivation needs for major of measurement and control technology and instrument under the background of digitalization, this paper proposes a digital demonstration teaching method of sensor principles for the core course "Sensor Principles". The digital demonstration teaching method of sensor principles is proposed based on fully considering the characteristics of the course "Sensor Principles", exploring the digital demonstration of sensor principles in response to the main problems in course teaching.

The digital demonstration teaching method includes three main parts at different stages of teaching: (1) the establishment of a digital demonstration database for sensor principles; (2) digital demonstrations in classroom teaching and post class database creation; (3) the real-time evaluation of the method and method improvement.

Based on this method, it could improve the current problem of lacking intuitive digital demonstration content in course teaching, as well as the problem of insufficient and inaccurate understanding of principles by students due to their lack of practical engineering experience.

This digital demonstration teaching method could increase the participation of students, stimulate their learning enthusiasm and forming a brave and positive academic philosophy to overcome difficulties. And this method provides new ideas for the construction of the core course "Sensor Principles" and the cultivation for major of measurement and control technology and instrument in the context of digitalization.

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