RESEARCH ARTICLE

Experimental teaching design and practice of human factors engineering for biomedical engineering

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Human factor engineering experiment is an indispensable part of biomedical engineering course, which builds the link between textbook knowledge and practical ability and covers the field of engineering, physiology, psychology, and mechanical technology, *etc*. In order to improve students' engineering practice ability, combined with current situation of the training of biomedical engineering professionals, the design and practice of human factors engineering experiment teaching were carried out in this study. The teaching experiment platforms were constructed including environment, physiology, and interaction intelligence sub-platforms. According to the platform and theoretical course, three experiment courses were designed to consolidate and mastery the textbook knowledge. 20 opening advanced human factor engineering experiment involving living space, medical equipment, and military installations were selected. The various teaching methods such as case study-based learning (CBL) teaching, flipped classroom, cross linkage, and case iteration were adopted to improve the taste of the course. Through this study, many students' self-designed experimental designs were revised and submitted to "Ergonomics" and other professional journals and public accounts, and their theoretical and practical skills were improved to a certain extent. The course necessity and satisfaction reached 100%, while the teaching quality satisfaction was 93.9% (31/33). Through teaching innovation, highlighting the "combination" features of military, medicine, and engineering, the experimental content could reflect the characteristics of the course and complement the theoretical content. It was of great significance for students to deepen their understanding of theoretical courses and exercise their scientific research ability.

Keywords: human factor engineering experiment; teaching; biomedical engineering; experimental design.

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Introduction

Human factors engineering is a comprehensive discipline which studies the cooperation of human-machine-environment system and improves human production efficiency. It is widely utilized in aerospace, military, medical, commercial products, and many other fields [1]. In the medical device industry, the vision of human factors engineering is directly related to the availability, usability, and convenience of medical devices, which is about safety and risk to the health care system [2]. It is of great practical significance to set up human factors engineering courses for biomedical engineering majors and carry out characteristic teaching activities for the innovative design of human factors engineering for medical equipment, which is because

biomedical engineering graduates are the main force of the medical device industry [3, 4]. The course of human factors engineering is characterized by strong practicality and a close combination of theory and practice. As a bridge connecting textbook knowledge and practical ability, experimental courses play an important role in improving students' professional cognition, innovative thinking, ability to analyze, and solve practical problems. It is also critical to improve students' understanding of the ideology of human-machine-environment system engineering [5].

Currently, there is no curriculum construction of "Human factors engineering for medical devices" for biomedical engineering in the colleges and universities in China. According to the principle of "wide range of knowledge and solid foundation", it should be the main way to enhance the theory and experiment teaching of human factors engineering in biomedical engineering majors and to innovate talents cultivation in the medical device industry with "human factors engineering design sensitivity". Human factors engineering is one of the professional courses of biomedical engineering with 40 class hours including 30 theoretical teaching class hours and 10 experimental hours including 2 final examination class hours. The experimental course is not only the supplement and perfection of theoretical teaching, but also the technical guarantee for the development of comprehensive experiment of final examination. The human factors engineering course is a practical course. In consideration of the specialty and course characteristics, two aspects should be paid attention to in the construction of experimental course content, which include the content of basic experiment that reflects the theoretical teaching content and professional basic knowledge, i.e., the basic experiment should be arranged after the chapter of human body system and operating environment, but before the man-machine system chapter. This arrangement is to verify the theoretical content and to deepen the understanding of basic methods. To explore the feasible new curriculum design mode of "cognitive experience + practical innovation" in colleges and universities, the other aspect is to inspire engineering sensitive and cultivate professional skills. Those measures enable students to observe life from the perspective of human factors engineering, and truly establish engineering sensitive and sustainable competence. This study focused on the design, construction, and implementation effect of experimental course based on the progress of human factors engineering course in our university.

Materials and Methods

Construction of teaching experiment platform

Referring to the construction experience in the colleges and universities in China, and considering our practical curriculum arrangement, the overall structure of human factors engineering experiment platform was designed (Figure 1) [6, 7]. According to the characteristics of human factors engineering course, the teaching experiment platform consisted of three sub-platforms. The subjects of sub-platforms were set up with environment, human body, and man-machine as the main objects. The platform of environmental parameter collection was used to calibrate the environmental conditions of the system. The platform of basic physiology was used to benchmark the body's own characteristics. The platform of intelligence interaction was used for high order human-machine experiment (H-M-E) design and dynamic data acquisition. Sub-platforms could satisfy higher complexity H-M-E system experimental requirements and cross-fused to each other. After that, ErgoLAB ergonomics analysis system (Kingfar International INC, Beijing, China) was employed to output visual reports such as signal processing and data analysis. The H-M-E Data Cloud Platform was based on campus area network, which was not applicable for internet. All the data was updated to H-M-E Data Cloud Platform for subsequent inspection.

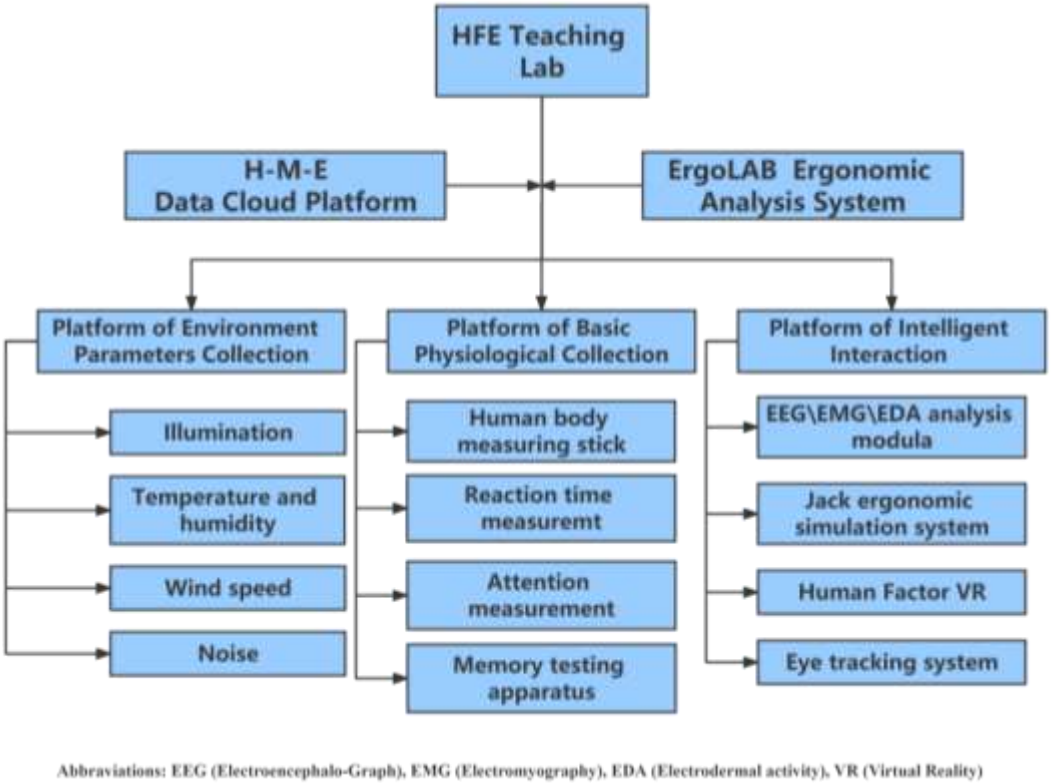

Figure 1. The framework of human factor engineering (HFE) teaching laboratory.

Curriculum provision

The contents of experimental curriculum should be based on the key points of theoretical curriculum. Therefore, when designing the topic, it was necessary to compile a comprehensive evaluation table according to the theoretical curriculum ability requirements, which included the key and difficult points of the other 14 chapters of the theoretical curriculum except the introduction. The book of "Human Factor Engineering" edited by Fu Guo and Shengsan Qian in 2021 (China Machine Press, Beijing, China) was selected as the textbook. A total of 8 people including 3 professional teachers and 5 student volunteers from the university were invited to conduct pre-evaluation of experimental projects. The content of the course was evaluated from the five dimensions of extension, improvement, interest, practicality, and comprehensiveness with scores from -3 to 3 indicating dissatisfaction or satisfaction as shown in Table 1 [8].

The experimental content was set according to the Likert scales. The teachers compiled lecture notes to keep implementation of teaching. The experimental content would be more in-depth by improving and refining the key point from the "textbook knowledge" to the 'life and production practice". The content list of the experimental course was shown in Table 2.

Advanced experiment

The experimental course of human factors engineering is not only the supplement and perfection of theoretical teaching, but also the technical guarantee for the process of comprehensive experiment of final examination. The teaching team closely focused on the talent training goal of biomedical engineering major and the training of students' thoughts and concepts. Then, the experimental course content and related class hours according to the theoretical course schedule were arranged [9]. According to the above ideas, the teaching team

Table 1. Likert scale for evaluation of content of course.

Experiment	-3 Strongly disagree	-2 Disagree	-1 Slightly Disagree	0 Nether agree nor disagree	1 Slightly agree	2 Agree	3 Strongly Agree
Brain-body load experiment	○	○	○	○	○	○	○
...	...	...	...	...	...	...	...
Anthropometric experiments	○	○	○	○	○	○	○

Table 2. List of human factors engineering experimental curriculum.

Name of Experiment	Type	Purpose	Instruments
Hypoxic environment experiment	Basic experiments	1. An understanding of hypoxic environment simulation methods. 2. Master the basic experimental design principles. 3. Master the bench experiment and its data analysis methods.	Steps, stopwatch, hypoxic mask, instantaneous memory tester, gauges, etc.
Brain-body load experiment	Research Experiments	1. Understand the standard methods of measuring and calculating brain and body load. 2. Understand the terminology and test items related to brain-body load testing. 3. Master basic data analysis ideas.	Power bicycle, concentration ability tester, multiple reaction time tester, etc.
Anthropometric experiments	Research experiments	1. Master the methods of human size measurement. 2. Master the method of deriving the proportional relationship between the main body dimensions and the height H. 3. Master the use of anthropometric data for desk and chair size design.	Anthropometric scales, 3D body size measurement software, Jack human factors analysis software, etc.
Perceptual engineering design experiment	Comprehensive experiments	1. Understand the content, steps and methods of research in perceptual engineering. 2. Master the methods of imaginative cognitive analysis of sample products by perceptual engineering design methods. 3. Master usability evaluation indexes and evaluation methods.	Eye movement meter, physiological signal measurement, usability evaluation scale, etc.
Final experiments	Comprehensive experiments	This part was conducted in the form of writing a course paper and reporting and defending, focusing on examining students' theoretical knowledge of human factors engineering to design experimental research, the ability to solve practical problems, and the ability to think creatively.	All the above hardware and software

arranged a 2-class final comprehensive experiment to formulate 20 open human factors engineering issues covering production, living places, medical equipment, and other fields, which highlighted the "Combination" professional features of medicine and engineering [10].

Teaching method

The knowledge content of human factors engineering curriculum involves a wide range, and the experimental course content is flexible and diverse. Single teaching method is difficult to meet the requirements of course teaching. In order to improve the classroom teaching effect, the teaching methods such as heuristic method and flipped classroom should be organized according to the experimental content. Thus, knowledge imparting is interesting and challenging.

(1) Case-based learning (CBL) teaching

CBL teaching included three steps. First of all, it was necessary to set up a virtual scene to guide students to describe the possible human factor engineering problems in this scene and analyze the causes of the problems. Secondly, the problems were decomposed into single points step by step, and solved one by one in combination with the theoretical course knowledge points. Finally, the solution in accordance with the law of human factors engineering was summarized and a report or paper was written [11].

(2) Flipped classroom

The experimental teaching process was designed around students. Through teacher demonstration and case explanation, the students were inspired to draw inferences from examples and stimulated their willingness to actively improve their learning and living environment. Encourage students to imagine the ideal working and living environment, implement group topic selection for students flipped classroom. The students would explain the design scheme with the help of multimedia components, and the teachers would score the design scheme. This method could fully mobilize students' subjective initiative in learning and expressing [12].

(3) Cross linkage

This method could break through the boundaries of human factors engineering and flexibly relate the skills students had mastered in basic courses, which not only deepen students' understanding of multiple courses simultaneously, but also cultivate their ability to propose engineering solutions according to practical problems [13]. For example, in the self-designed test "Usability Design of CT Machine human-computer interaction interface", students firstly should master the CT related knowledge in medical imaging, and then, combined the basic principles and design rules in the three chapters of Human Factors Engineering including anthropometry, workspace design, and usability design. The students should use the drawing skills of Modern Engineering Drawing and 3D printing technology for console design and controller model printing. Integrating discrete knowledge points into a project through the linkage of textbook knowledge and skills could improve students' participation and teaching effect.

(4) Case iteration

This method included selecting excellent cases from students' self-developed experiments and composing them into the corresponding chapters of theoretical teaching. Using CBL could introduce abstract textbook knowledge into concrete engineering practice. On the one hand, it could enlighten students to observe life with engineering thinking, and further, it could help to improve the teaching and research level of teaching faculty and promote the virtuous cycle of teaching and learning [14].

Design validation

After nearly three years of demonstration and construction, the teaching group carried out two rounds of Human Factors Engineering for the 2018 and 2019 biomedical engineering junior students in our university from 2021. In addition, the teaching team also designed the

Table 3. Single choice question in the course evaluation.

Question	Excellent	Good	Average	Poor
Importance and Necessity	○	○	○	○
Interestingness	○	○	○	○
Adequacy of Teaching Preparation	○	○	○	○
PPT Courseware Completeness	○	○	○	○
Teaching logicality	○	○	○	○
Conformability of Teaching and Experiments	○	○	○	○
Innovation Encouragement	○	○	○	○

Table 4. Self-developed experimental topics of some students.

Title	Experiment content
Research on the influence of emotion regulation and attention based on color matching theory	Experiments are conducted based on approximate color matching and complementary color matching to explore the effects of approximate color matching on mood level and complementary color matching on attention level.
Study on the optimization scheme of classroom in relay building based on Dialux EVO	Based on Dialux EVO, which calculates the illumination distribution in the classroom, it can significantly improve students' learning efficiency and listening quality by replacing the light source and light distribution to meet the national standard lighting requirements.
Usability design of human-computer interaction interface of CT machine	Based on the eye-movement technology, eye-movement information such as gaze time and gaze position of the human-computer interaction interface of the CT machine is analyzed and compared to evaluate the usability of the human-computer interaction interface and make suggestions for improvement.
Human factors engineering evaluation and improvement design of a university cafeteria	Taking a university cafeteria as the research object, based on the results of the questionnaire and the theoretical approach of ergonomics, the design of the cafeteria is improved to meet the current shortcomings so that the cafeteria can bring more convenience and comfort to the life of students in the university.
Improved design of human factor engineering for field rescue equipment	By investigating the problems of human factors engineering in the practical application of NJ2046 multi-functional field ambulance, such as instrument rack, infusion pump setting, sponge cushion, foldable stretcher, ambulance bed, etc. Put forward suggestions to improve the usability and combat effectiveness of this ambulance.

questionnaire form to collect students' opinions about curriculum setting, content arrangement, teaching methods, teaching problems, faculty evaluation, and other aspects. The teaching team also paid close attention to the students' advice about experiment course construction and revolution. The questionnaire was conducted anonymously at the end of the course assessment. A total of 33 questionnaires were distributed and were all recovered with validation. The questions in the questionnaire were listed in Table 3.

Results and discussion

Many students' self-developed experimental reports were revised and submitted to "Ergonomics" and other professional journals and public accounts. Students could also design the experiments based on their own interests and laboratory construction conditions. Table 4 showed some of the experimental topics proposed by students. The theoretical and practical skills of students had been significantly improved. As a new course, there were inevitably some problems and deficiencies in teaching practice. In order to widely listen to the students' opinions, the teaching team set up weekly Q & A to get timely feedback from the students' opinions and suggestions. This strategy could modify the teaching method. The results showed that the course necessity was 100%, and the teaching quality satisfaction reached 93.9% (31/33). More than half of the students suggested that more attention should be paid to the content of experimental courses including going out for observation and setting up special research topics. The teaching group would gradually enrich the teaching content of the experimental course according to the actual conditions in the future process.

After analyzing the cultivation characteristics and the inner connection with the major of biomedical engineering, the necessity and importance of experimental course establishment of human factors engineering was demonstrated. Combined with the characteristics of the course, the teaching experiment platform was built. The teaching content was designed according to teachers' survey and students' evaluation. On this basis, a comprehensive experimental topic selection was drawn up. These content designs were using multi-dimensional teaching methods and highlighting the "Combination" characteristics of the university, which could promote the positive cycle of teaching and learning while improving the teaching effect. Relying on subjective and objective evaluations and feedbacks to improve the teaching content and methods, the training capacity and quality of innovative talents in biomedical engineering were improved.

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