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Exploration of Innovative Teaching Modes for the Course Intelligent Medical Signal Processing

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Abstract

Intelligent medical signal processing is a core technology in modern medicine. As a compulsory course for the intelligent medical engineering major, the course "Intelligent Medical Signal Processing" has a direct bearing on the quality of talent cultivation. However, the traditional teaching model suffers from problems such as outdated teaching content, single teaching methods, and unreasonable assessment methods, which make it difficult to meet the demands of the industry. To address these issues, this paper designs an innovative teaching model from multiple dimensions: reforming course objectives to construct a cultivation system covering "knowledge, ability, and quality"; optimizing the teaching system by adjusting teaching content and improving teaching methods; adopting an online-offline hybrid teaching model; and reforming assessment and evaluation models. Practice shows that this model significantly enhances students' learning interest and efficiency, deepens their understanding and application of knowledge, improves teaching satisfaction, and lays a solid foundation for subsequent courses. The innovative teaching model has achieved good results.

Keywords: .Intelligent Medical Signal Processing; Teaching Mode; Innovative Thinking; Online-Offline Hybrid Teaching

1. Introduction

In the development of modern medicine, intelligent medical signal processing has become an extremely critical core technology [1]. With the in-depth integration of multiple disciplines such as biomedical engineering and information technology, medical signal processing technology has developed rapidly, moving from traditional simple signal analysis to an intelligent and precise processing stage. In the field of disease diagnosis, through the intelligent processing of various medical signals (e.g., electrocardiographic signals, electroencephalographic signals, and electromyography signals), doctors can detect early signs of diseases more accurately and timely, gaining valuable time for patients' treatment.

The course "Intelligent Medical Signal Processing" is a compulsory professional course for the intelligent medical engineering major. It aims to apply the principles and methods of engineering to solve biomedical problems and improve human health. Through this course, students will learn about the characteristics of various biomedical signals, master the composition of medical signal data acquisition systems, the selection of sampling parameters, and the design methods of various digital filters and their medical applications. Based on modern information technology, the course deeply integrates diversified teaching modes such as theoretical lectures, practical operations, case analysis, group collaboration, and online learning, aiming to build an interactive, content-rich, and practice-oriented learning environment.

As an important course for cultivating professionals in related fields, the teaching quality of Intelligent Medical Signal Processing directly affects students' mastery of knowledge and skills in this field. However, the traditional teaching model has many problems in terms of course content, teaching methods, and practical links, making it difficult to meet the current demand for talents in intelligent medical signal processing in the medical field. Therefore, exploring innovative teaching modes for this course is of great practical significance [2].

2. Research Status at Home and Abroad

Foreign countries started earlier in the teaching of intelligent medical signal processing courses and have accumulated rich experience. Many well-known universities focus on the integration of theory and practice in curriculum design and adopt diversified teaching methods. Stanford University in the United States introduces a large number of practical cases and scientific research projects into the course, allowing students to learn and apply knowledge through practice. It also emphasizes interdisciplinary teaching, integrating knowledge from medicine, engineering, computer science, and other disciplines into the course to cultivate students' comprehensive abilities.

In terms of teaching methods, foreign universities widely use Problem-Based Learning (PBL) and Project-Based Learning (PjBL). These methods can stimulate students' learning interest and improve their autonomous learning and problem-solving abilities. At the same time, foreign universities also use advanced teaching technologies and platforms (e.g., online teaching platforms and virtual laboratories) to provide students with more convenient and rich learning resources.

In recent years, domestic universities have also gradually attached importance to the teaching reform of intelligent medical signal processing courses and carried out some explorations and innovations in teaching content and methods [3-5]. Some universities have added content related to cutting-edge technologies such as artificial intelligence and deep learning to the course to adapt to the development needs of the discipline [6-7]. Shanghai Jiao Tong University has introduced deep learning algorithms into the course for the classification and diagnosis of medical signals, enabling students to understand the latest technological development trends.

In terms of teaching methods, domestic universities have also begun to adopt case teaching and group cooperative learning to improve students' participation and learning effects [8-9]. At the same time, some universities have strengthened practical teaching links by establishing professional laboratories and practice bases to provide students with practical opportunities. However, there are still some shortcomings in domestic course teaching: the update of course content is not timely enough to fully reflect the latest research results in the discipline; the practical teaching links are relatively weak, and the cultivation of students' practical and innovative abilities needs to be strengthened; the innovation of teaching methods is insufficient, failing to give full play to students' subjective initiative.

An analysis of the research status at home and abroad shows that although certain achievements have been made in the teaching of intelligent medical signal processing courses both domestically and internationally, there are still areas that need improvement and refinement. In terms of course content, it is necessary to further strengthen the connection with practical applications, update teaching content in a timely manner, and reflect the latest development trends of the discipline. In terms of teaching methods, further exploration and innovation are required to give full play to students' subjective initiative and improve their learning interest and enthusiasm. In terms of practical teaching, it is necessary to strengthen the construction of practical teaching links to enhance students' practical and innovative abilities [10-12].

3. Problems in the Traditional Teaching Model

3.1 Outdated Teaching Content, Disconnected from Industry Development

Outdated teaching content is a prominent problem in traditional courses, mainly reflected in two aspects. First, the update of knowledge is not timely, making it difficult to keep up with the technological iteration speed in the field of intelligent medical signal processing. Currently, deep learning algorithms such as Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), Long Short-Term Memory (LSTM), and Gated Recurrent Units (GRU) have demonstrated excellent performance in medical signal classification, feature extraction, and disease diagnosis. However, some courses still focus on traditional algorithms such as Fourier transform and wavelet transform, with insufficient explanation of emerging deep learning algorithms. This leads to a disconnect between what students learn at school and the actual needs of the industry. After graduation, when entering medical enterprises or scientific research institutions, students need to spend a lot of additional time learning new technologies to meet the application requirements of deep learning algorithms in projects.

Second, the lack of integration of cutting-edge technologies limits students' horizons. Technologies such as artificial intelligence, big data, and cloud computing provide new paths for medical signal processing. For example, artificial intelligence can realize automatic diagnosis of medical images, and big data can mine potential patterns in massive signals. However, the proportion of these cutting-edge technologies in existing courses is extremely low, failing to reflect their importance. Students have a vague understanding of the concepts and principles of cutting-edge technologies and are even unable to apply them to practical problems, which directly affects the cultivation of their comprehensive quality and innovative abilities.

3.2 Single Teaching Method, Emphasizing Theory over Practice

The traditional teaching method has obvious limitations. The primary problem is that it focuses on theoretical lectures while neglecting the cultivation of practical skills and thinking. In class, teachers mostly focus on explaining the concepts, principles, and algorithm derivations of signal processing. Although this ensures the systematicness of knowledge, it places students in a passive position of receiving knowledge. For example, when explaining Fourier transform, knowledge is delivered only through formula derivation and theoretical introduction. Although students can memorize formulas and basic principles, they lack a deep understanding of how to apply Fourier transform to actual medical signal processing, making it difficult to integrate theory with practice. This model also easily makes students feel that the course is boring, reducing their learning interest and enthusiasm.

In addition, the lack of interactive and practical links further exacerbates the shortcomings of teaching. Classroom interaction is mostly in the simple form of "teacher asks and students answer," lacking in-depth discussions. Students find it difficult to give full play to their subjective initiative, and their thinking is limited. Practice is the key to transforming theory into ability. However, in traditional teaching, practical opportunities are scarce. Due to limitations in equipment and time, students can only conduct simple operations and cannot carry out complex experiments (e.g., multi-signal fusion processing and development of a complete processing system). As a result, when facing practical problems, students struggle to apply the knowledge they have learned to solve them, leading to weak practical abilities.

3.3 Unreasonable Assessment Method, One-Sided Evaluation Dimension

The unreasonableness of the assessment method is mainly reflected in the imbalance of evaluation focus and the incompleteness of the evaluation process. On the one hand, it focuses on the assessment of theoretical knowledge, making it difficult to comprehensively evaluate students' abilities. Most courses mainly adopt written examinations to test students' mastery of theoretical knowledge. Students may cope with exams by rote memorization of formulas and knowledge points. For example, although there are questions about algorithm formula derivation in written examinations, students can complete them proficiently. However, in practical applications, they cannot select or optimize algorithms according to the characteristics of medical signals, which fails to reflect their practical and innovative abilities and is not conducive to the cultivation of these abilities.

On the other hand, the lack of process-oriented evaluation makes it impossible to provide timely feedback and comprehensive assessment. Traditional evaluation mostly relies on final exam results, ignoring process indicators such as students' classroom performance, homework quality, and participation in group projects. This makes it impossible for teachers to timely detect and provide guidance on problems existing in students' learning process (e.g., incomplete understanding of knowledge points and poor homework quality). Students may continue to learn with these problems, leading to the accumulation of more issues. The lack of process-oriented evaluation also makes it impossible to comprehensively assess students' comprehensive quality, such as teamwork ability, communication ability, and autonomous learning ability—abilities that are crucial for students' future career development but not reflected in the traditional assessment method.

4. Design and Implementation of the Innovative Teaching Model

4.1 Reform of Course Objectives

First, we established hybrid teaching course objectives from three dimensions: knowledge imparting, ability cultivation, and quality improvement:

(1) Knowledge Imparting: Through this course, students will systematically and comprehensively understand the content and disciplinary structure of intelligent medical signal processing, and be able to independently sort out and construct a knowledge system.

(2) Ability Cultivation: Through learning and operating verification, comprehensive, and innovative experiments, students will be able to design experiments using theories, summarize theories through experiments, and independently carry out research on extended projects. The course also cultivates students' ability to use digital signal processing methods and tools to solve practical problems in medical signals, guiding them to apply relevant theories and algorithms of the course to convert practical medical problems into corresponding theoretical calculations by establishing mathematical models, and comprehensively use knowledge of mathematics, natural sciences, and engineering technology for analysis and solution.

(3) Quality Improvement: The course cultivates students' theoretical and application qualities in intelligent medical signal processing, improves their innovative qualities and comprehensive professional qualities, and comprehensively enhances their personal core competitiveness to cultivate comprehensive application-oriented talents for the country.

Furthermore, based on the progressive theory, the course carries out online-offline hybrid teaching through pre-class independent preview, in-class participatory learning, and post-class advanced learning, forming an integrated cultivation model of students' cognition, practice, expansion, and innovation.

4.2 Optimization of the Course Teaching System

The original course teaching system was optimized to develop theoretical and practical courses with the concept of "teacher as guide, student as main body." The optimized course teaching system mainly focuses on two aspects: optimizing teaching content and improving teaching methods (as shown in Figure 1).

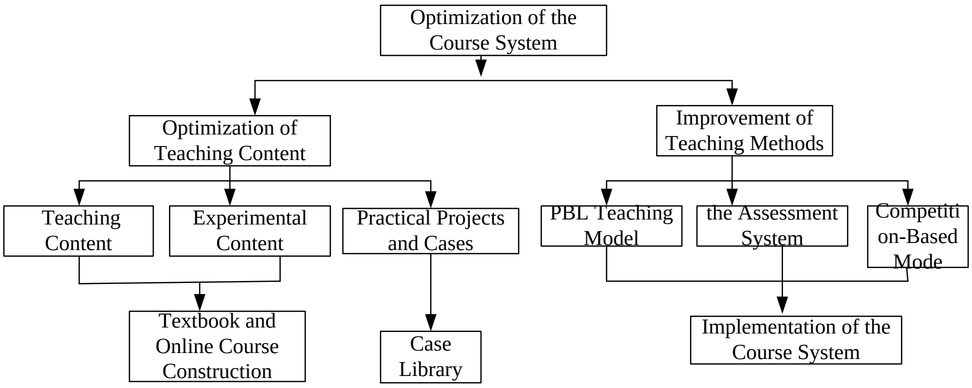

Figure 1. Effect Diagram of the Optimized Course System

4.3 Improvement of Teaching Content and Methods

(1) Optimization of Classroom Teaching Content: Textbooks that match the teaching syllabus and are suitable for students' progressive learning were selected. Knowledge points in the selected textbooks that do not fit the syllabus were selectively removed, and cutting-edge and practical knowledge points suitable for students of this major were added. For example, the derivation of random signal processing in the selected textbooks involves many formulas, which is difficult for undergraduates to understand. This part of the content can be appropriately simplified and replaced by programming simulations of case projects using this knowledge. Through graphical presentations, students' understanding is improved while enhancing their learning interest.

At the same time, based on the experience of multiple rounds of teaching, a knowledge graph (as shown in Figure 2) was formed, textbooks suitable for students of this major were compiled, and corresponding online courses and course question banks were developed.

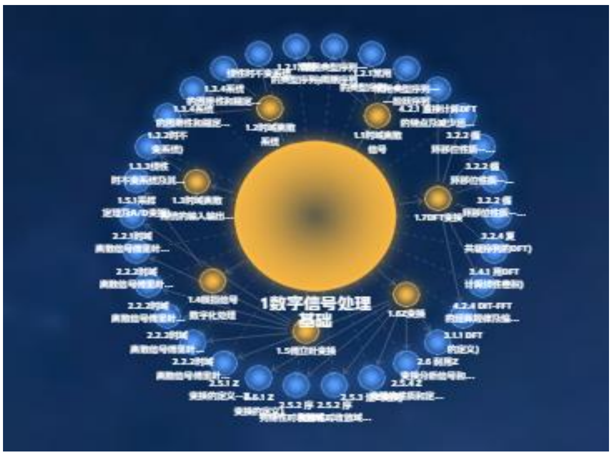

Figure 2. Knowledge Graph

(2) Selection and Design of Experimental Projects and Simulation Software: A series of complete experimental projects and experimental simulation software matching the teaching syllabus were selected and designed. For example, in the teaching process of this course, MATLAB and DigScope software were used simultaneously to conduct simulation experiments on electrocardiographic signal processing (as shown in Figure 3), meeting students' needs for experimental platforms.

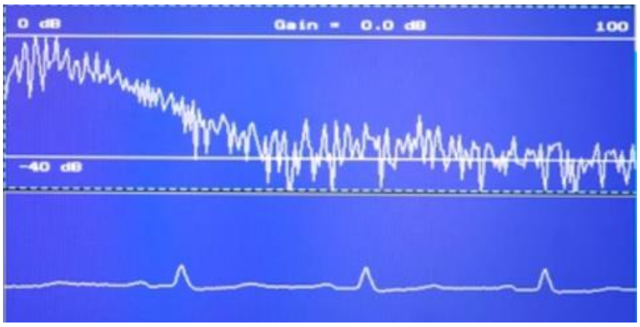

Figure 3. Spectrum of Electrocardiographic Signals

(3) Development of Project Cases: Project cases consist of three parts: basic knowledge theory teaching, project implementation plan analysis, and hands-on practice in the laboratory. These cases organically integrate theory and practice, as well as teacher teaching and student activities. Furthermore, opportunities for school-enterprise co-construction and engineers entering the classroom were fully utilized. Cooperation in teaching was carried out with affiliated hospitals and relevant enterprises, and students were led to visit hospitals and enterprises to observe the collection and processing of biomedical signals, as well as the software operation processes of doctors and enterprise staff. Through these visits, students deepen their understanding of the course, clarify its application in practical engineering, and truly improve their ability to analyze and solve problems.

(4) Adoption of PBL Teaching Model: Students are guided by problems, requiring them to apply theoretical knowledge learned in the course to solve practical problems. In addition to mastering the knowledge related to the subject, students are also required to expand their knowledge scope through extensive research, learning, and practice. Heuristic, discussion-based, and research-based innovative teaching methods were adopted, adhering to the principles of "concise teaching and inspiring thinking" to fully develop students' personalized creative potential, guide them to raise questions, think independently, and explore actively.

4.4 Improvement of the Teaching Model

A hybrid teaching model of "teaching platform + auxiliary teaching platform + blackboard writing + multimedia teaching" was adopted.

With students as the center, relying on the MOOC resources of NetEase Cloud Classroom and the Chaoxing Fanya teaching platform, effective integration of online and offline teaching, MOOC resources and SPOC mode, online and in-person teaching, and blackboard writing and multimedia was achieved. Advantages were complemented, resources were allocated rationally, and teaching was implemented in a progressive manner. Resource allocation is shown in Figure 4.

Figure 4. Resource Allocation

4.5 Reform of the Assessment Method

Flipped Classroom: University classrooms have gradually become a "one-man show" of teachers, with students having less and less sense of participation. To improve students' learning enthusiasm, on the basis of classroom lectures and in-class questions, relevant research directions were assigned to students, requiring them to independently collect materials, make PPTs, and give in-class presentations. This not only improves students' learning enthusiasm, initiative, and sense of participation but also enhances their team awareness and cooperation spirit . Some flipped classroom PPTs are shown in Figure 5.

Figure 5. Demonstration of Partial Flipped Classroom PPTs

4.6 Evaluation of Teaching Effects

(1) Improvement of Learning Interest and Efficiency: Through integrating theory with practice and adjusting teaching content, students' learning interest and efficiency were significantly improved. Students participated in learning more actively, and their understanding and mastery of course content were deeper.

(2) Deepened Understanding and Application: By introducing familiar physiological electrical signals for practical exercises, students were able to integrate theoretical knowledge with practice, deepening their understanding and application of theoretical knowledge. This teaching method not only stimulated students' learning interest but also improved their practical abilities. Figure 6 shows examples of MATLAB-based medical signal processing GUI interfaces designed by some students.

(3) Improvement of Teaching Satisfaction: A questionnaire survey was conducted to evaluate the effect of teaching reform. The results showed that teaching satisfaction was significantly improved. Students recognized the new teaching methods and content, believing that this model better meets their learning needs and interests . The questionnaire survey results are shown in Figure 7.

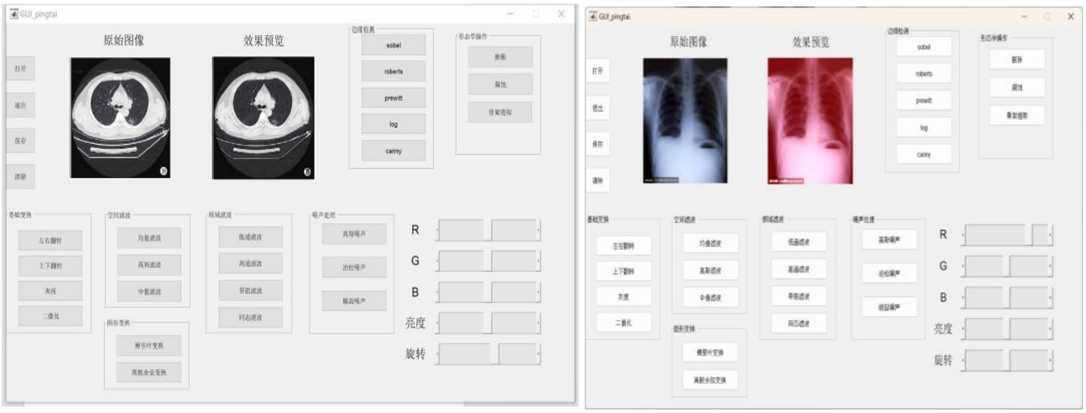

Figure 6. Examples of MATLAB-Based Medical Signal Processing GUI Interfaces Designed by Students

Figure 7. Questionnaire Survey Results

4.7. Evaluation of Course Objective Achievement

An evaluation of the achievement of course objectives formulated in accordance with the professional training program and the course syllabus was conducted. Following the principle of equal distribution of "excellent, medium, and poor," 29 statistically significant samples of students' learning achievements were selected, accounting for 50% of the total number of students taking the course. The achievement of each course objective by the sample students was calculated separately, and scatter plots were drawn based on the results (as shown in Figures 8-10).

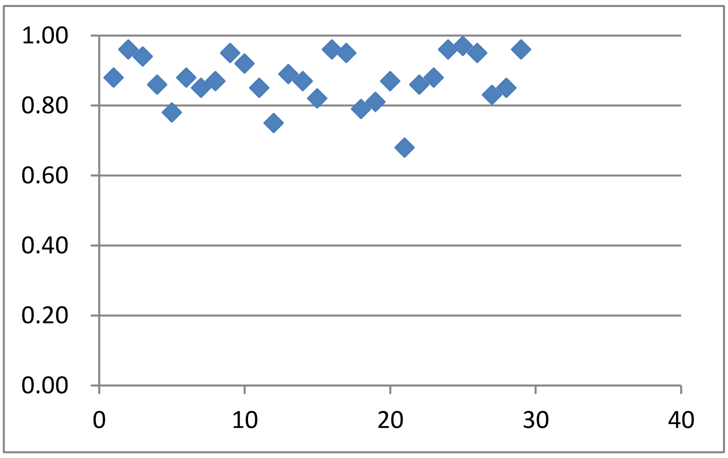

Figure 8. Achievement of Course Objective 1 by Individual Students

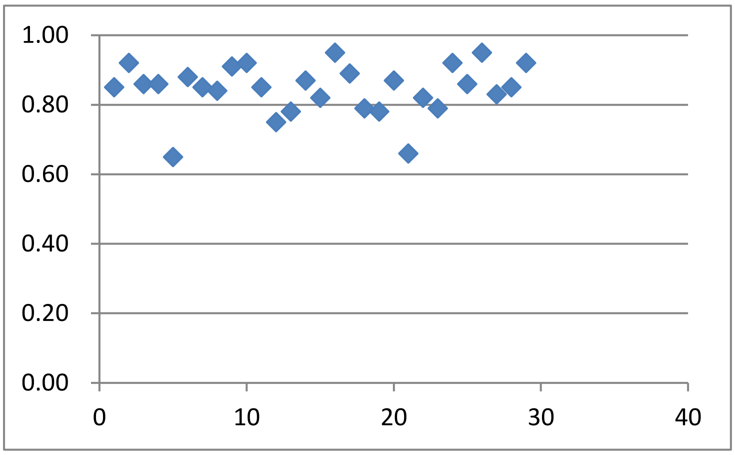

Figure 9. Achievement of Course Objective 2 by Individual Students

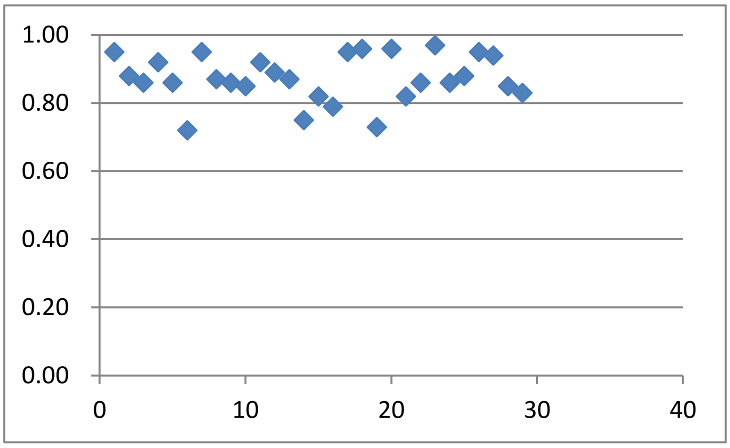

Figure 10. Achievement of Course Objective 3 by Individual Students

5. Conclusion

The teaching reform of the "Intelligent Medical Signal Processing" course not only has a positive impact on this course but also provides great help for subsequent courses such as "Digital Signal Processing." Students can more easily understand the relevant concepts and principles in subsequent courses, laying a solid foundation for further learning. Continuously improving teaching methods and exploring more suitable teaching models for students are also the focus of future research. Teaching methods such as Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL) will be introduced to stimulate students' learning interest and initiative, and cultivate their autonomous learning ability and innovative thinking. In combination with technologies such as artificial intelligence and big data, personalized teaching will be realized to provide students with personalized learning suggestions and guidance based on their learning situation and characteristics, thereby improving teaching effects.

In conclusion, the exploration of the innovative teaching model for the "Intelligent Medical Signal Processing" course has achieved good results. Through the innovative teaching model, students' learning interest and efficiency have been improved, their understanding and mastery of course content have been deepened, and teaching satisfaction has been significantly enhanced, laying a solid foundation for the study of subsequent courses.

References

[1] Lin L, Sun S. Exploration of Practical Teaching in the Course of Modern Medical Signal Processing. China Modern Educational Equipment,2024,(13):122-124.

[2] Zhang C,Xie H,Fu L, et al.. Exploration and Practice for Applied Course Teaching of Biomedical Signal Processing Based on Combination of Medical-engineering. Education Teaching Forum, 2019,(24):138-140.

[3] Liu Y, Zhou J, Zhang J, et al. Exploration on the Teaching Practice of Curriculum Ideology and Politics in the Course of Biomedical Signal Processing Journal of Higher Education,2025,11(15):180-183.

[4] Wu S, Lin L, Yang C. A Brief Analysis on the Establishment and Application of the New Teaching System for the Course Biomedical Signal Processing. Industry and Information Technology Education, 2016(1): 20-24.

[5] Li L, Lv Y, Yang D, et al. Exploring Interdisciplinary Digital Signal Processing Practices in Medical Engineering in the Context of Emerging Engineering Education. Journal of Jiaxing University, 2024, 36(06): 136-140.

[6] Wu Y, Lin L. Automatic lung segmentation in CT images using dilated convolution based weighted fully convolutional network. Journal of Physics: Conference Series,2020(1):012032.

[7] Zhang G, Lin L, Wang J. Lung nodule classification in CT images using 3D denseNet. Journal of Physics: Conference Series, 2021(1): 012155.

[8] Li X, Zhang X, Si B, et al. Research on Training Strategy of Medical Engineering Integration Talent Based on Learning Compass Under New Engineering Disciplines. China Continuing Medical Education, 2023, 15(01): 171-174.

[9] Wang W, Xiao Z, Zhang F, et al. Exploration on the Innovation of Medical-Engineering Integration Teaching Mode for the Course "Intelligent Medical Image Processing". Technology Style, 2025, (22): 97-99.

[10] Lin L, Wu S. Integrated Experimental Platform of Signal and System Course Based on Jupyter Notebook. China Modern Educational Equipment, 2021(17): 16-18.

[11] Zhou Y. Exploration and Practice of Cultivating Students' Practical Abilities with Disciplinary Competitions as the Core Means— A Case Study of Shanghai University of Electric Power. Science & Technology Vision. 2016.(22): 162-162.

[12] Wang L. Enhancing College Students' Employability Through the Second Classroom as a Platform. Course Education Research, 2016, (19): 231-232.