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Reform and Practice of Digital Signal Processing Course Guided by OBE Concept

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Abstract:

Digital Signal Processing is a compulsory basic course for electronic information majors. Implementing the OBE (Outcome-Based Education) concept in the teaching process of Digital Signal Processing can effectively improve the teaching quality of the course, which is of great significance for improving the quality of professional teaching and students' professional quality. The Digital Signal Processing course team at the North University of China has carried out reforms and practices in several aspects, including classroom teaching mode, experimental teaching, and performance evaluation mechanism. After three semesters of practice, the average qualitative achievement rate of the course objectives has increased by 18.7%, and the quantitative achievement rate has risen by 1.65%. This indicates that students' interest in the course, course application ability, engineering practice ability, and team collaboration ability have all been greatly improved.

Keywords:

Digital signal processing
Curriculum reform
OBE

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1. Introduction

Digital Signal Processing is a compulsory basic course for electronic information majors that combines strong theoretical and practical elements. Together with the Signal and Systems course, it forms the foundation of information processing theory and holds an important position in the academic curriculum system. Digital Signal Processing is based on advanced mathematics and complex variable functions, integrating knowledge from subjects such as signals and systems [1]. It is highly theoretical, involves abstract concepts, and requires the establishment and analysis of numerous mathematical models, resulting in a relatively large knowledge system. The basic theories and methods of Digital Signal Processing are not only applied in traditional fields like communications, measurement, and control engineering, but also widely used in areas that require signal transmission, processing, and analysis, such as industrial control and manufacturing, biomedicine, economics, and social science. Implementing the OBE (Outcome-Based Education) concept in the teaching process of Digital Signal Processing can facilitate a shift from an input-oriented to an outcome-oriented approach, helping students acquire knowledge and develop skills through independent exploration activities like problem-solving, experimentation, investigation, information gathering, expression, and communication. Reforming the Digital Signal Processing course can effectively improve the quality of professional teaching and is of great significance for enhancing students' professional qualities.

The characteristics of the Digital Signal Processing course include strong theoretical content, abstract concepts, clear physical meanings, and a strong emphasis on practicality. Throughout the course, two practical issues need to be addressed: (1) students' mastery of the mathematical theoretical foundation and understanding of the physical world have a significant impact on their grasp of the course, so it is necessary to consider how to improve these two aspects; (2) ways to enhance student's ability to apply the theoretical learning of this course to practical and professional situations. These issues must be resolved to implement OBE educational reform in this course.

2. Problems in the teaching of Digital Signal Processing course

Taking the North University of China as an example, the teaching of the Digital Signal Processing course faced the following issues that were not aligned with the OBE concept before the reform.

2.1. Teacher-centered teaching mode, students passively accept

This is typical input-oriented learning, with a limited range of teaching methods and low student engagement. In the teaching process of digital signal processing, the teacher-centered teaching mode is often adopted, with a single teaching method primarily relying on blackboard instruction and PPT presentations. There is limited interaction between teachers and students, resulting in low student interest in learning. Domestic textbooks on digital signal processing emphasize the completeness of theoretical systems, containing a lot of content and focusing on the derivation and analysis of basic concepts and theories. They require students to have a solid foundation in advanced mathematics and complex variable functions. However, some students have a relatively weak mathematical foundation, making it somewhat difficult for them to learn. The textbooks do not introduce cases for knowledge points, and the provided application cases are relatively few and not up to date with current technologies. This fails to stimulate students' curiosity and interest in independent learning.

2.2. The lack of extensibility in teaching content, time, and space limits students' access to learning outcomes

The course of digital signal processing mainly covers two aspects: signal spectrum analysis and filter design. Currently, the teaching method still focuses on teachers presenting basic theories and applications in the classroom. Most students generally do not prepare before class and have no access to relevant online or other teaching resources beyond textbooks and teachers' lecture notes. Comparing the teaching process of related courses at schools such as MIT in the United States, it is found that foreign teachers explain less content in class than their domestic counterparts, and their classroom teaching methods are more diverse. Teachers play a more guiding role. However, the amount of homework assigned by foreign schools is relatively large, requiring students to spend three times the classroom teaching time to complete. This significantly enhances students' independent learning abilities and problem-solving skills.

2.3. Single practical aspect and insufficient analysis of problems

Course experiments use MATLAB programming to complete tasks such as system analysis, signal analysis, system design, and signal filtering, which is the approach adopted by most schools nowadays [2]. MATLAB is characterized by its simplicity of implementation, and it provides ready-made functions for most signal-processing methods. However, there are some issues: (1) Current experimental requirements mainly emphasize the application of theory, verification, and analysis of results, but this content is often lacking in students' reports due to its simplicity; (2) Using only MATLAB for experiments results in a relatively simple implementation process, leading to a lack of understanding of engineering applications and backgrounds among students.

Engineering education professional certification should be reflected in the design of teaching modes for various courses, and the content covered needs to be re-planned based on traditional teaching, with a focus on cultivating student's ability to solve engineering problems and professional quality. To embody the OBE concept and address the issues in the digital signal processing course, this article proposes reforms in teaching modes, experimental content and structure, and performance evaluation.

3. Reform plan and achievements

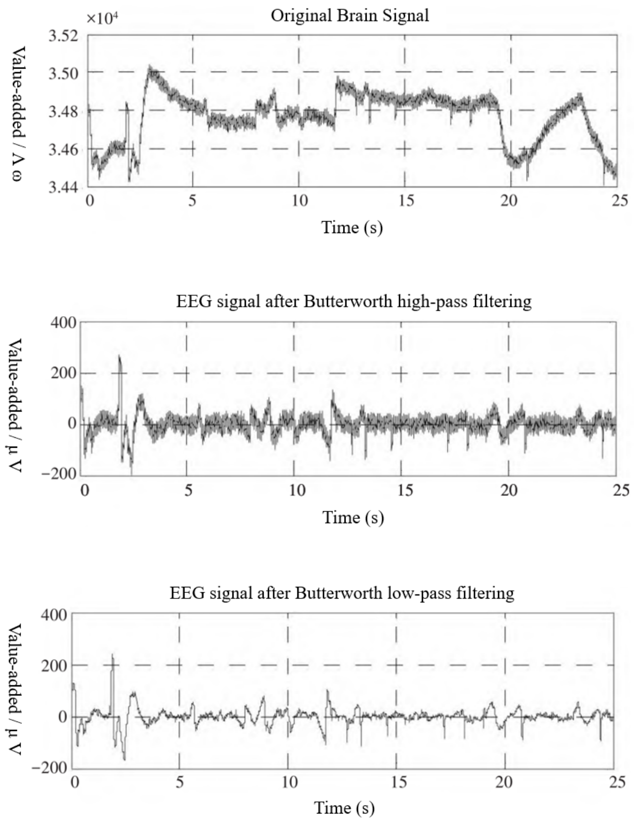
The Outcome-Based Education (OBE) concept, which is oriented toward achievements, emphasizes two main questions: (1) What learning outcomes do teachers want students to achieve? (3) How can teachers effectively help students achieve these learning outcomes? Therefore, it is necessary to conduct research on the knowledge system, curriculum system, and practical system of students majoring in the course. Various forms of research activities should be carried out to establish a teaching model and evaluation mechanism that aligns with the OBE concept.

3.1. Reform of classroom teaching model

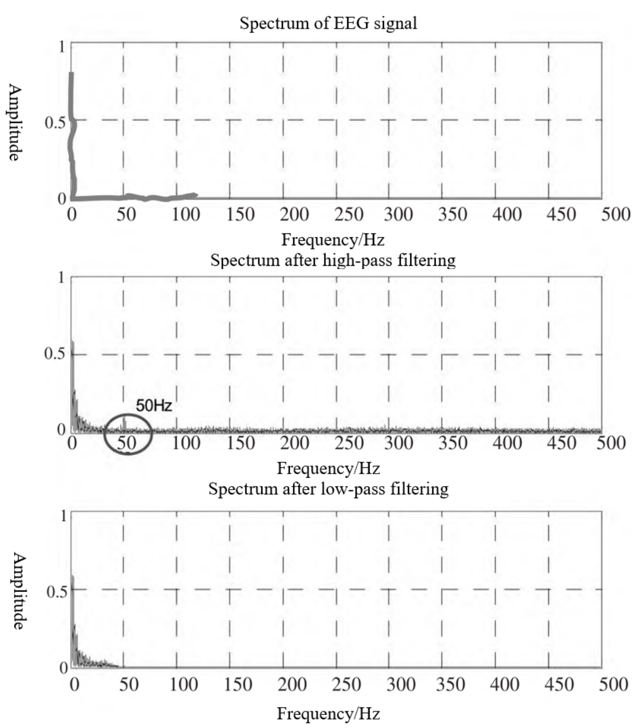
Teachers have implemented a new "student-centered" theoretical teaching reform, introducing flipped classrooms into the teaching process. The reformed teaching places greater emphasis on the construction of student's knowledge related to digital signal processing, the cultivation of their abilities, and the improvement of their qualities. In the implementation process, pre-class, in-class, post-class, and extended tasks need to be designed [3,4]. Pre-class: Relying on resources such as textbooks, reference books, quality course websites, and online MOOCs, pre-class previews are arranged to guide students to discover problems. In-class: Inquiry-based teaching methods are used to facilitate discussions in the classroom, and preset questions are explored to guide students to think about knowledge points. Seminars are conducted focusing on key and difficult points in teaching. Through interactions between teachers and students, as well as among students, activities are completed that are student-centered and fully utilize creativity and team collaboration skills, mobilizing students' enthusiasm for learning and enabling teachers to grasp students' learning status in real time. Post-class: Students are required to complete certain assignments to consolidate what they have learned. Extension: Comprehensive project assignments are designed, requiring students to complete them in groups. This cultivates students' abilities to think independently, consult materials, use modern tools, communicate, and express themselves.

Taking the case study activity of how to use IIR filters to process pulse, electrocardiogram (ECG), and electroencephalogram (EEG) signals as an example, the topic is released before class, allowing students to research and gain a preliminary understanding of the basic characteristics of the signals being processed, as well as the types and parameters of possible filters and their advantages and disadvantages. Students are then required to propose initial solutions. During the class, group representatives present the principles, content, advantages, and disadvantages of their adopted solutions. All proposed solutions and core parameters are then discussed and compared by students and teachers. After class, each group further improves their respective solutions based on the discussions, strengthens the description and processing of details, and summarizes the knowledge points used and the key issues or parameters that need to be considered in the solution.

Figure 1(a) shows students participating in an innovation competition using an 8-channel wet electrode EEG cap to collect EEG signals. Combining the content learned in the course, students use FFT to perform spectral analysis on the signals and propose a filter design scheme combining high-pass and low-pass filters for signal processing. The high-pass filter is used to remove low-frequency interference such as baseline drift, while the low-pass filter is used to eliminate power frequency interference and other high-frequency interference, as shown in **Figure 1(b)**. Students also use the processed signals for cognitive recognition. During the analysis and design process, students compare the performance of band-pass filters with high and low-pass filters, concluding that band-pass filters have a small transition



(a) Signal acquisition



(b) Signal analysis and filtering

Figure 1. Processing EEG signals using IIR filters.

band, high filter order, and high implementation cost. The performance of Butterworth, Chebyshev, and elliptic filters was also analyzed and compared, concluding that under the same design specifications, Butterworth filters have the highest order and elliptic filters have the lowest order. This comprehensive case study helps students understand the connotations of the two main tasks in the digital signal processing course and how to apply what they have learned to solve practical problems, greatly stimulating students' enthusiasm for learning and improving teaching effectiveness. According to a related survey, 66% of students believe that classroom discussions are very helpful for understanding, mastering, and expanding relevant content, while 34% of students find them helpful.

3.2. Reform of experimental teaching

Currently, the experiments in this course emphasize the application of theory. Addressing issues such as the simplicity of the overall implementation process and the lack of understanding of engineering applications and backgrounds, the course team organically integrates theoretical learning, experiments, and course design. This forms a teaching model that progresses from theoretical learning to theoretical verification, to small-scale design, and finally to large-scale comprehensive design. Each stage highlights key points and builds progressively, promoting students' practical engineering application abilities and innovative capabilities.

The experimental teaching design of the course follows a learning approach that starts with verification, then moves to integration, and finally to design. This progressive approach aligns with students' cognitive laws regarding relevant knowledge points [5]. The main objective of the experimental teaching design is to help students learn to apply DFT theory for spectrum analysis, interpret issues related to spectrum analysis, and utilize computers to perform spectrum analysis of signals. Additionally, it aims to analyze the performance of designed filters, provide filter design schemes based on performance indicators or design requirements, design IIR and FIR digital filters, and implement filter design and signal filtering using computers. The course team has made corresponding adjustments to the specific details of digital signal processing experiments and added comprehensive application-based experiments.

In addition to requiring the output of signal amplitude-frequency and phase-frequency characteristics, the new experiments also require students to output signal diagrams or data results for each calculation step. This enables students to analyze changes in the time and frequency domains of signals and draw conclusions, placing greater emphasis on the principles and processes of numerical calculation. In filter design and application, there is a stronger focus on understanding the frequency characteristics of designed filters. Filtering specific engineering signals, such as electrocardiogram signals, is also included to deepen students' understanding of filter design principles.

For instance, in the case of FIR filters, the old experiment outline only required filter design and frequency characteristic analysis without covering filter applications. However, the new experiment outline emphasizes filtering multi-frequency sinusoidal signals according to specified requirements, placing greater emphasis on integrating theoretical knowledge with practical problems. This approach aims to cultivate students' abilities to analyze and solve problems.

Comprehensive experiments are conducted through a student-selected approach. Taking the digital audio processing design experiment as an example, students are required to record their voice signals, perform spectrum analysis based on frequency resolution, design corresponding high-pass and low-pass filters, and achieve effects such as fast playback, slow playback, single echo, multiple echoes, reverberation, and harmony. The purpose of this experiment is to comprehensively apply the knowledge of digital signal processing learned to achieve the integrated design of a digital system.

In another example, the cepstral system design experiment, students record a voice signal and use a cepstral system to exchange the high and low frequencies of the signal. This scrambles the frequency components of the original signal, reducing intelligibility and serving as a form of speech encryption. Students then restore the signal using the same cepstral system at the receiving end and evaluate the encryption effect by plotting the time and frequency domain waveforms before and after encryption and decryption. The goal of this experiment is to utilize knowledge such as spectrum analysis, parameter selection, and the design of high-pass and low-pass filters from digital signal processing for the integrated design of a digital system.

During experimental design and data analysis, efforts should be made to strengthen students' abilities in using signal processing equipment and software, programming, academic communication, and report writing.

Through analyzing students' reflections in laboratory reports and survey questionnaires, it has been found that the reform of experimental teaching has cultivated students' abilities to think independently, search for information, use modern tools, communicate, and express themselves. This has enhanced students' enthusiasm for learning and improved their practical application skills. The course team conducted a pilot program by adding optional experiments to a class of students majoring in telecommunications engineering. Survey results from this class showed that 71% of students believed that the addition of optional experiments was very helpful in understanding the course and applying relevant content in practical situations, while 29% found it helpful.

A student's experimental experience and understanding are as follows: Through the experiment, I reviewed the theoretical knowledge learned in the course and consolidated the key points and difficulties of the learned knowledge. The study first consulted relevant materials to understand the working principle of the cepstral system and found that it is mainly achieved through multiplication transformation with trigonometric functions combined with low-pass and high-pass filtering. Therefore, the focus is on understanding the mathematical transformation principles involved in the multiple multiplication processes of the original signal with trigonometric functions, as well as the design of low-pass and high-pass filters. In the experiment, the Chebyshev filter was chosen, which performed better than the Butterworth filter. Many problems were encountered during the experiment, most of which were due to inexperience with MATLAB-related functions. However, after reviewing the relevant function HELP, these functions were finally used correctly, and this process was very rewarding. Since the previous experiments involved the design of IIR filters, it was relatively easy to design the Chebyshev filter. In summary, through these experiments, the content of digital signal processing, spectrum analysis, and filter design knowledge were comprehensively reviewed and the theory was combined with practice and verified in practice.

3.3. Reform of achievement evaluation mechanism

According to the teaching needs of digital signal processing courses and referring to the teaching syllabus, a test bank including theoretical knowledge points, MATLAB implementation of related knowledge points, and comprehensive design topics has been established. This serves as an effective teaching auxiliary system, forming an achievement evaluation mechanism that combines written examinations, classroom discussions, and project assignments.

The effectiveness of teaching reform is generally measured by the degree of achievement of course objectives. The evaluation method for the degree of achievement of course objectives includes both quantitative and qualitative evaluations. Quantitative evaluation mainly adopts a weighted calculation evaluation method based on the degree of achievement of course objectives, while qualitative evaluation mainly adopts a questionnaire survey method. Both evaluations are converted into normalized values, requiring both to be greater than 0.65 for the objective to be achieved. If either is less than 0.65, it is considered not achieved, and the overall achievement value is taken as the smaller of the two.

Taking students majoring in telecommunications engineering as an example, according to the distribution of goal achievement in **Table 1**, students' academic performance has significantly improved from the 2018 academic year to the 2021 academic year. The goal achievement situation shown in **Table 1** is divided into quantitative analysis and qualitative analysis. From the perspective of qualitative indicators: compared with the first semester of the 2018–2019 academic year, the achievement of Goal 1 increased by 11.7% in the first semester of the 2019–2020 academic year, and by 19.5% in the first semester of the 2020–2021 academic year. Similarly, the achievement of Goal 2 increased by 11.7% and 19.5%, respectively, in these periods. For Goal 3, the achievement increased by 7.6% in the first semester of the 2019–2020 academic year compared to the first semester of the 2018–2019 academic year, and by 15.2% in the first semester of the 2020–2021 academic year. The proportions of each goal achievement to the total achievement are 0.35, 0.4, and 0.25, respectively. Based on this, the total achievement for the first semester of the 2020–2021 academic year compared to the first semester of the 2018–2019 academic year increased by 18.4%, indicating a significant improvement in qualitative indicators. From the perspective of quantitative indicators, the total achievement for the first semester of the 2020–2021 academic year increased by 1.9% compared to the first semester of the 2018–2019 academic year.

Table 1. Distribution of goal achievement

Course time	Objective 1: Master basic concepts, basic transformations, and their relationships (0.35)		Objective 2: Be able to apply DFT theory to perform spectrum analysis and explain related issues; be able to design IIR and FIR digital filters based on performance indicators, and analyze the impact of different factors on the filtering effect (0.4)		Objective 3: Use computer software to implement digital signal spectrum analysis, filter design, signal filtering, and other processing (0.25)	
	Quantitative	Qualitative	Quantitative	Qualitative	Quantitative	Qualitative
The first semester of 2018–2019 academic year	0.89	0.77	0.90	0.77	0.84	0.79
The first semester of 2019–2020 academic year	0.87	0.86	0.81	0.86	0.83	0.85
The first semester of 2020–2021 academic year	0.92	0.92	0.91	0.92	0.85	0.91

This suggests that through curriculum reform, students' mastery of course knowledge has improved to a certain extent.

Both evaluations are converted into normalized values, and the overall achievement is taken as the smaller of the two, forming the total degree of achievement. As shown in **Figure 2**, it can be seen that students' course achievement is increasing year by year.

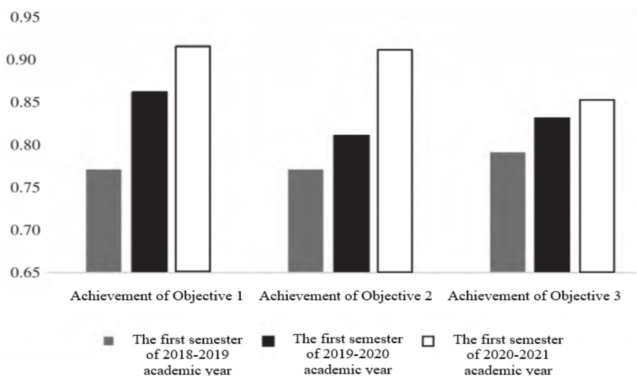


Figure 2. Achievement of objectives from 2018 to 2021

4. Conclusion

Taking the major of communication engineering as a pilot, after three semesters of reform and practice, and in-depth study of the connotation of the OBE concept, this study has written a teaching outline and experimental outline that meet the standards of engineering education professional certification. A teaching model of a digital signal processing course suitable for teaching objects was proposed, optimizing the teaching content and improving the teaching methods. Practice has shown that this reform has achieved significant results, improving students' learning initiative, and enhancing their communication skills, engineering practice abilities, and teamwork abilities.

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Disclosure statement

The authors declare no conflict of interest.

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