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Exploring Teaching Reform of "Digital Signal Processing" Course in the Context of Information Technology

Hongjian Jia*, **Tianyang Xu**
Heilongjiang University, Harbin 150080, China

Corresponding author: Hongjian Jia, jiahongjian@163.com

Abstract:

"Digital Signal Processing" is one of the core professional courses in electronic information, and the course itself has strong theoretical and practical aspects. Aiming at the common problem of separation between theory and practice in current course teaching, this article explores the teaching mode of the course with practical teaching as a breakthrough and proposes a demand-oriented, engineering background-integrated, and future-oriented practical teaching program for digital signal processing. By fully utilizing the existing information platform for practical course design and management, and through close integration with the engineering background, the study aims to build a solid foundation knowledge system for students, cultivate their engineering practice abilities, and establish a new teaching mode for "Digital Signal Processing" oriented towards applied talent cultivation.

Keywords:

Digital Signal Processing
Practical course teaching
Engineering practice
Teaching reform

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1. Introduction

"Digital signal processing technology" is a fundamental course for electronics and communication-related disciplines and plays a crucial role in undergraduate education. With the development of microprocessor technology, important theoretical achievements in digital signal processing have been transferred to digital technology, becoming a significant cornerstone in modern engineering and scientific fields such as electronics and communication technology, speech and image processing, and artificial intelligence [1,2]. However, due to its rich knowledge content, abstract theories, and strong engineering practicality, digital signal processing also poses certain difficulties for traditional undergraduate teaching [3]. In the development of the "Digital Signal Processing" course, Ingles and others integrated MATLAB software into classroom teaching, achieving a combination of theoretical and practical aspects of the course [4]. Beijing University of Aeronautics and Astronautics explored hierarchical experimental teaching for the course, deepening students' understanding of basic concepts through experimental teaching [5]. Since then, various universities have implemented improvements such as developing software teaching platforms and enriching classroom teaching levels based on their characteristics [6,7]. With the goal of "cultivating high-quality, cross-disciplinary, and outstanding engineering and technological talents" proposed in the context of new engineering, traditional classroom teaching methods have begun to shift towards meeting the needs of new engineering talent cultivation [8].

Xu *et al.* (2022) aimed to promote the integration of professional education in universities with economic and social development, exploring reforms to address issues in the teaching of "Digital Signal Processing" [9]. Wang *et al.* (2023) attempted to explore course teaching based on the OBE educational philosophy, improving students' sense of achievement by optimizing teaching design, classroom teaching, and after-class evaluation [10]. Li *et al.* (2020) proposed a three-level teaching reform method for digital signal processing, focusing on "basic theory as the main body," "application technology as the traction," and "cutting-edge disciplinary issues as highlights," to better apply course content in engineering practice [11]. Mei *et al.* (2023) integrated project cases and cutting-edge technologies with the core content of the course, adopting various teaching modes such as classic model case explanation, comprehensive case virtual simulation, and innovative application case discussion to improve the quality of course teaching [12]. Du *et al.* (2023) explored bilingual teaching of digital signal processing in the context of new engineering and achieved corresponding results in the course construction process [13]. The above studies have practiced and explored course teaching reforms from different perspectives. Given that "Digital Signal Processing" is a compulsory course for undergraduate students majoring in electronics and information, this study aims to cultivate students' interest, enhance their abilities, and stimulate innovation and practicality. The study explores teaching modes suitable for the information technology background, hoping to provide references for teaching research in related professional courses.

2. Teaching method combining theory and practice in the context of informatization

In the traditional teaching mode of "Digital Signal Processing" courses, theoretical explanation and formula derivation are necessary classroom teaching links. However, this mode can cause corresponding problems, such as some students only focusing on theoretical learning and ignoring practical applications, or the boredom of theory triggering students' fear of difficulty, leading to a decrease in learning interest. With the improvement of informatization in Chinese universities, integrating practical content into theoretical teaching using informatization methods will become a new trend in practical teaching in the context of new engineering disciplines. To achieve the cultivation of applied talents and increase the fit between teaching links and talent abilities, the following explores the teaching method combining theory and practice for the "Digital Signal Processing" course in the context of informatization from practical course design and management.

2.1. Design method for practical courses based on MATLAB

The "Digital Signal Processing" course plays a pivotal role in bridging the gap between preceding and succeeding courses in electronic information majors. It integrates content from various foundational courses such as advanced mathematics, complex variable functions, circuit analysis, signals and systems, and is characterized by its strong theoretical foundation, abstract concepts, and numerous formulas. Due to students' varying mastery levels of these foundational courses, purely theoretical instruction can lead to a lack of initiative during the learning process. MATLAB, as an essential tool for electronic information majors, boasts efficient numerical computation capabilities, comprehensive graphical processing abilities, and a wide range of powerful application toolboxes. This study aims to enhance students' problem-solving skills through MATLAB programming and explore practical course design methods based on MATLAB.

Firstly, multiple levels of practical teaching content are designed according to students' different mastery levels. The practical course is divided into two parts:

verification experiments and innovative experiments, accounting for 40% and 60% of the course, respectively. Verification experiments focus on understanding basic knowledge points from the textbook, such as Fourier transforms and filter design. Innovative experiments emphasize the integrated application of knowledge to practical problems like digital image processing and speech signal processing. In verification experiments, students complete fixed teaching tests to consolidate their understanding of key concepts. For innovative experiments, instructors set tasks at three levels (A, B, and C), corresponding to practical problems in different domains. Level A tasks involve signal processing issues in interdisciplinary fields, such as implementing Orthogonal Frequency Division Multiplexing (OFDM) in MATLAB during communication processes. Level B tasks address real-life problems, like using MATLAB to filter images corrupted by noise during transmission. Level C tasks involve fun and interesting problems related to digital signal processing, like composing the melody of "Singing for the Motherland" using MATLAB's sound function. Each level includes multiple similar sub-tasks, assigned coefficients of 1.0, 0.9, and 0.8, respectively, allowing students to make personalized choices based on their interests and abilities.

Secondly, teaching methods are designed based on the practical course content. Verification experiments primarily use the lecture method, guiding students to review basic knowledge from corresponding chapters in theoretical courses and explaining the process of achieving tasks using MATLAB. Abstract theories are presented to students through mathematical derivations and graphical animations, assisting them in completing theoretical verifications and clarifying the impact of parameter changes on digital signal processing performance. Innovative experiments adopt a flipped classroom approach, handing over the initiative to students, guiding them to utilize online resources effectively, and cultivating their self-study awareness and academic presentation skills. The specific process includes students selecting topics, grouping based on chosen topics, independently researching and implementing task requirements, presenting on-site in groups of three, assessment by the instructor, and allocating grades based on individual contributions.

Finally, students are evaluated based on their comprehensive performance. The scores from verification and innovative experiments are aggregated to form the final grade for the practical course, considering the students' self-selected experimental projects. Since innovative experiments dominate the grade distribution, the assessment results provide an objective evaluation of students' learning and innovative practical abilities. By completing the "Digital Signal Processing" practical course using MATLAB, an essential tool in engineering fields, students not only gain access to extended classroom knowledge through various channels but also improve their proficiency in using MATLAB software. This approach enhances the cultivation of students' practical abilities while achieving teaching objectives, equipping them with the skills to integrate theoretical knowledge with practical experience and analyze and solve engineering technology problems.

2.2. Practice course management method based on information platform

The redesign of practical courses signifies that traditional course management methods have become inadequate to meet diversified course demands. Therefore, it is imperative to update course management practices accordingly. Online management software supported by an information platform serves as a crucial tool for the practical course of "Digital Signal Processing," and the hybrid teaching model assisted by multiple platforms has achieved positive results in practice. The course management discussed in this section primarily involves three components: explanation and demonstration of experimental courses, issuance and collection of practical tasks, and comprehensive assessment of grades.

The explanation of experimental courses primarily relies on offline classroom teaching, including theoretical knowledge review and demonstration of verification experiments. To facilitate students' ability to repeatedly watch the key points and operational steps explained in class after school, it is planned to convert the class content into videos and publish them on the management platform for students to view multiple times. Taking the autonomous learning platform Xuexitong as an example, the aforementioned function can be realized in the course material uploading section. Additionally, the platform can introduce numerous excellent online course resources such as MOOCs and shared courses, enhancing the breadth of knowledge acquisition for students. Since the platform can track students' viewing and downloading frequencies, it enables a comprehensive understanding of students' learning status through data analysis. Furthermore, the management platform should also feature an online live-streaming function to accommodate situations where students are unable to attend class due to unexpected circumstances.

The outcomes of multi-level practical tasks based on MATLAB are typically presented in the form of M-files, graphic files, and audio files. Utilizing the management platform for task issuance and collection represents a more efficient management approach. Setting task release and submission times on the platform indirectly urges students to complete learning tasks on time. Students can leverage the platform's question-asking function to promptly raise doubts encountered during the learning process. Course instructors and participating classmates can discuss under relevant topics, forming a course communication "forum" for answering students' questions and resolving their doubts. Additionally, the platform's homework collection section allows for convenient grading of student assignments. Compared to traditional grading methods, the online mode enhances the overall efficiency of course progression.

In terms of grade assessment, scoring points are set based on the relationship between verification practice course content and knowledge objectives. After annotating each student's assignment, a grade analysis table reflecting the achievement of knowledge objectives for specific tasks is generated. Upon completing annotations for all task assignments, the system can produce a comprehensive grade analysis table for verification practices, indicating students' mastery of all knowledge points. For innovative practice course content, grades are allocated based on each team member's actual contribution to the task, resulting in a comprehensive grade assessment method that reflects students' mastery of basic theories and their level of engagement in practical innovation. In summary, utilizing an information platform for the design and management of practical courses can accommodate various forms of classroom teaching, facilitate the issuance and collection of practical tasks in different formats, and enhance the efficiency of course-related work. The hybrid teaching model assisted by multiple platforms can improve the monotony of traditional classroom teaching, boost student engagement, and cultivate students' team collaboration skills.

3. Exploration of teaching models in the context of engineering projects

The aforementioned practical curriculum reforms, combined with the existing informatization platform, provide students with opportunities to solve specific problems based on fundamental knowledge and cultivate their initial understanding of practical engineering issues. However, relying solely on practical courses to enhance theoretical learning in digital signal processing still leaves a gap compared to the emphasis on subject practicality, comprehensiveness, and close integration with industrial technology in the context of new engineering disciplines. For popular information processing technologies such as face recognition, speaker recognition, and deep learning, the fundamental knowledge covered in digital signal processing courses serves as the cornerstone for problem-solving. Organically integrating popular engineering cases in these fields with the core content of the courses is beneficial for enhancing students' interest in learning and their ability to apply what they have learned.

3.1. Teaching model based on scientific research project-driven approach

The teaching model based on a scientific research project-driven approach needs to integrate the professional backgrounds of course instructors, combining research and teaching organically. This model requires fully utilizing the research foundation of the course instructors, selecting the research components related to digital signal processing from the scientific research projects they are undertaking, and breaking them down into a series of sub-problems suitable for undergraduate students, thus initially establishing an engineering case library. The content related to textbook knowledge points in the actual scientific research process should be organized, and the theoretical knowledge points involved should be explained through the analysis of engineering problems, demonstrating the phased achievements of the project to the students. In addition, some project content can be integrated with practical courses, guiding students to initially establish a connection between theory and practice through the instructors' facilitation and leading discussions on other basic knowledge points involved in the project to solidify students' professional knowledge systems. Under the aforementioned teaching model, further coursework can be set up to guide students to reflect on current hot topics or difficult issues in the engineering field, stimulating their interest in scientific research and allowing them to appreciate the actual market demand for professionals. Teaching combined with scientific research projects enables undergraduates to be exposed to a real research environment early in the classroom, which is conducive to stimulating their intention to continue their studies in their current field of expertise and cultivating their independent learning abilities in scientific research.

In the teaching model driven by scientific research projects, it is necessary to reasonably extend the basic knowledge in the textbook. Taking "speaker recognition in complex environments" as an example, students need to grasp the specific concepts and theories of digital signal processing courses involved in this task and understand the deeper methods and models required to complete the task. For instance, to accurately recognize speakers in complex environments, background noise interference needs to be removed first. To achieve noise suppression, the concept of filters needs to be introduced, which is covered in the digital signal processing course syllabus, and explaining it in the context of engineering problems is more helpful for students' understanding. However, solely relying on filters cannot fully solve the problem of accurate speaker recognition. Further analysis of speech signals is required, introducing the concepts of sampling and feature extraction. Students have had initial exposure to sampling theory in the precursor course "Signals and Systems," while feature extraction needs to be explained in combination with knowledge from pattern recognition courses. This layered approach not only effectively connects the knowledge points across chapters but also vividly demonstrates to students how to use their learned professional knowledge to process speech signals in complex backgrounds, achieving an organic combination of theory and practical problems. Furthermore, based on the analysis results of the "speaker recognition task in complex environments," students are guided to think deeply, recognizing that real-world problems are far more complex than textbook scenarios, and strengthening their awareness of applying what they have learned.

3.2. Seminar courses driven by market demand

While fully understanding the needs of scientific research, grasping market demand is also a crucial aspect that students need to focus on in their future studies and job searches. Because undergraduates spend most of their time in full-time study on campus and have limited understanding of the professional market, introducing corporate mentors to conduct seminar courses can effectively increase students' cognition of their chosen major, form a more systematic understanding of theoretical courses, and better align with the output-oriented student training model in the context of new engineering disciplines.

Seminar courses related to enterprises can be established based on existing school-enterprise cooperation or utilizing the professional backgrounds of course instructors and conducted through the teaching college. There are various ways to select corporate mentors, such as inviting graduates of the college who work in related enterprises or scientific research institutes, inviting industry peers of the course instructors, or relying on government school-enterprise cooperation plans to find technical personnel from cooperating enterprises to serve as corporate mentors at the college level. Based on the actual situation of the corporate mentors, the seminar courses can be targeted as online meetings or offline classroom modes, allowing corporate mentors to fully communicate and discuss with students. Using their workplace experiences as examples, they can explain to students how to apply professional knowledge to work tasks and answer students' considerations and doubts about their future careers. To enhance students' understanding of market demand and scientific research hotspots, the frequency of seminar courses can be appropriately increased, and 1–2 corporate mentors from different fields can be invited to share their workplace experiences with students during each course cycle. Seminar courses driven by market demand can promote students' awareness of future career planning. Since the digital signal processing course is conducted in the first semester of the third year, students will soon face the issue of professional internships. The corporate mentor system helps establish a two-way relationship between enterprises and students interested in participating in internships. Based on mutual inspection wishes, students can be arranged to intern at corresponding enterprises, facilitating the smooth implementation of the internship segment of the professional training program.

Seminar courses not only provide cooperation and exchange between students, enterprises, and scientific research units but also help students deeply understand the connotation and extension of the course, promoting their deep understanding and mastery of theoretical knowledge. Combining the exploration of teaching reform models with the cultivation of students' practical abilities can improve students' ability to solve complex engineering problems and cultivate applied talents that meet national strategic needs.

3.3. Training mode for students' self-learning ability facing the future

The reform of the teaching model for the "Digital Signal Processing" course is not confined to the classroom, and the end of the course does not signify the conclusion of students' learning. The reform should always focus on the future, fostering students' correct understanding of self-study and continuous learning, and helping them develop habits of sustained learning throughout the entire course.

In practical curriculum reform, due to limited class hours, the knowledge that teachers can impart to students is finite. Some extended knowledge content requires students to master it through self-study after class. Therefore, students are required to select appropriate reference materials for auxiliary learning. The practical course discussed in this study is implemented using MATLAB software. Ingles' classic textbook, "Digital Signal Processing Using MATLAB," can serve as an introductory guide for students to understand the engineering background of digital signal processing. This book emphasizes MATLAB implementation methods for digital signal processing and de-emphasizes theoretical derivations, making it suitable for use in practical courses. Additionally, English-language textbooks enable students to use English as a tool for acquiring knowledge, which is a key focus of future-oriented training models.

If students encounter theoretical confusion during the learning process, they can refer to Oppenheim's classic textbook, "Discrete-Time Signal Processing" (Third Edition). This book provides clear theoretical derivations and detailed analyses of knowledge points. It includes three levels of exercises, ranging from easy to difficult, allowing students of different learning levels to choose appropriately. It is suitable as a reference book for students' advanced learning. Furthermore, the book has a corresponding Chinese version, which students can use as an auxiliary learning tool. This model strengthens students' proficiency in English during the theoretical knowledge learning process, providing convenient conditions for their subsequent professional course studies.

Simultaneously, students are encouraged to actively conduct literature searches and subscriptions to timely obtain the latest academic developments, broaden their horizons beyond the classroom, and enrich their understanding of professional progress. They should fully utilize the online database resources provided by the school, such as the IEEE Journal of Selected Topics in Signal Processing, IEEE Transactions on Signal Processing, and Signal Processing, to learn about cutting-edge knowledge in digital signal processing. During free seminar sessions, students are organized into groups to exchange their gains from the information retrieval process. This model effectively assists students who intend to further pursue studies in this field. Even if students do not pursue research work in related fields in the future, the independent learning methods and continuous learning habits cultivated through the "Digital Signal Processing" course will become long-term assets for them.

Regarding the reform of the teaching model for the digital signal processing course, the approach explored in this study not only places stricter demands on the course instructor but also increases the demand for class hours. Based on satisfying the traditional theoretical class hour requirements, it is suggested to add a 4-hour enterprise mentor discussion session and a 4-hour student independent discussion session, equivalent to expanding the original theoretical course by 8 hours. Furthermore, to meet the educational goals in the context of new engineering disciplines, it is recommended to introduce a 16-hour practical session on digital signal processing to enhance students' comprehensive understanding and application abilities in professional courses.

4. Conclusion

This study addresses the issues of students' low interest and inconsistent mastery in the "Digital Signal Processing" course, which are caused by abstract theoretical knowledge and complex engineering backgrounds. By combining the actual needs of the job market, it explores the reform ideas for theory and practice teaching in the context of informatization, forming an integrated teaching model suitable for undergraduates in electronic information majors. Guided by the educational goals in the context of new engineering disciplines, this study not only strengthens the theoretical foundation but also takes into account the cultivation of students' engineering practice and innovation abilities. Firstly, the practical course content is designed to cultivate students' hands-on skills. Secondly, with engineering problems as the background, the degree of fit between theoretical courses and practical applications is improved. Finally, students are guided to strengthen their self-directed learning awareness using information platforms. Through exploring the teaching model of digital signal processing courses, this study injects vitality into the originally boring theoretical courses, enhancing students' interest and engagement. The proposed theory and practice teaching reform methods can help students master digital signal processing theories and provide new ideas for the construction of professional courses for undergraduates in electronic information majors.

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Disclosure statement

The authors declare no conflict of interest.

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