

Integration of Professional and Innovation-Entrepreneurship Education in the "Signals and Systems" Course: A Three-Stage Pedagogical Model and Practice

Jiaying Yu, Jing Chu, Meifeng Zhang, Jie Guo

School of Photoelectric Engineering, Changzhou Institute of Technology, Changzhou, Jiangsu, 213032, China

Abstract: Against the backdrop of "Emerging Engineering Education" (NEE) initiatives, the deep integration of professional education with innovation and entrepreneurship education has become a critical direction for reform in higher engineering education. This paper addresses the persistent challenges in teaching the core course "Signals and Systems" for electronic information majors, including excessive theoretical abstraction, disconnection from engineering practice, and insufficient innovation cultivation. We propose a three-stage pedagogical model characterized by progressive advancement through "theoretical construction—engineering practice—innovation expansion." By developing four representative teaching cases—audio noise reduction based on frequency-domain analysis, wireless sensor network data acquisition based on the sampling theorem, millimeter-wave radar signal processing based on system function analysis, and switched-mode power supply control based on Laplace transform—the model bridges core knowledge points such as convolution theorem, Nyquist sampling theorem, system function, and Laplace transform with authentic industrial scenarios. This approach achieves a pedagogical transformation from "knowledge transmission" to "competency cultivation" and "innovation enlightenment." Practical implementation demonstrates that this model effectively enhances students' engineering capabilities and entrepreneurial awareness, providing a replicable and scalable paradigm for the integration of professional and innovation-entrepreneurship education in analogous courses.

Keywords: Signals and Systems; integration of professional and innovation-entrepreneurship education; pedagogical reform; engineering practice.

1. Introduction

"Signals and Systems" serves as a foundational core course for electronic information majors, encompassing theoretical frameworks for continuous-time and discrete-time signal analysis, time-domain and transform-domain system analysis. It functions as a critical bridge connecting prerequisite circuit fundamentals with subsequent courses such as Digital Signal Processing and Communication Principles. However, conventional instruction suffers from three prominent deficiencies: first, theoretical derivations overemphasize mathematical formalism, hindering students from establishing physical intuition; second, laboratory exercises predominantly involve verification-oriented simulations lacking authentic engineering contexts; third, the curriculum remains disconnected from industrial demands and innovative practice, resulting in a pronounced "learning-application gap" among students.

With the deepening implementation of the "Mass Entrepreneurship and Innovation" strategy, the Ministry of Education has explicitly mandated the integration of innovation and entrepreneurship education throughout the entire talent cultivation process^[1, 2]. The integration of professional and innovation-entrepreneurship education (hereinafter referred to as "PIE integration") does not constitute a simplistic grafting of entrepreneurial knowledge onto professional courses; rather, it requires the excavation of inherent innovation and entrepreneurship genes within professional knowledge. Through authentic problem-driven instruction, engineering project-based learning, and industrial

scenario immersion, PIE integration seeks to achieve the organic unification of knowledge transmission, competency cultivation, and value shaping. Drawing upon our practical experience in curriculum development for "Signals and Systems," this paper explores a three-stage pedagogical model characterized by progressive advancement through "theoretical construction—engineering practice—innovation expansion." Through the concrete implementation of four representative teaching cases, we validate the instructional efficacy and scalability of this model^[3, 4].

2. Overall Design of the PIE Integration Pedagogical Model

2.1. Design Philosophy

This model employs "frequency-domain thinking" as the core methodological thread, following the progressive relationship of "cognitive patterns—engineering logic—innovation pathways" to construct a three-dimensional pedagogical framework integrating "professional depth, engineering relevance, and innovation height"^[5]. Specifically, professional depth refers to consolidating the mathematical foundations and physical connotations of core theories including Fourier transform, sampling theorem, and system function; engineering relevance denotes enabling students to appreciate application scenarios and constraints of technologies through authentic industrial cases; innovation height guides students in transitioning from a "technical parameter optimization" mindset toward a "user demand

satisfaction" mindset, thereby cultivating product awareness and entrepreneurial cognition.

2.2. Model Architecture

The pedagogical model adopts a structure of "three-stage progression and four-link coupling." The three-stage progression organizes instructional content for each chapter according to the temporal ratio of "theoretical construction (45 minutes)-engineering practice (75 minutes)-innovation expansion (45 minutes)." The four-link coupling comprises: pre-class industrial case micro-lectures to stimulate learning motivation; in-class project-based experiments to train engineering competencies; post-class innovation workshops to incubate creative solutions; and extracurricular disciplinary competitions to validate instructional outcomes. These four links form a closed loop enabling continuous iterative optimization^[6].

2.3. Integration Pathways

The entry pathways for PIE integration are embodied in "four alignments": first, alignment between knowledge points and industrial technologies, such as associating the convolution theorem with audio chip noise reduction algorithms; second, alignment between experimental tasks and engineering standards, such as requiring filter designs to meet signal-to-noise ratio improvement metrics; third, alignment between discussion topics and business models, such as analyzing cost structures and competitive advantages of technical solutions; fourth, alignment between evaluation dimensions and entrepreneurial competencies, incorporating teamwork and feasibility analysis into the assessment system.

3. Design and Implementation of Representative Teaching Cases

3.1. Case 1: Audio Noise Reduction System Design Based on Frequency-Domain Analysis

This case corresponds to the chapter "Frequency-Domain Analysis of Continuous-Time Systems," with the convolution theorem and system frequency response as core knowledge points^[7]. Instruction commences with situational immersion through three comparative audio segments (clean speech, speech with white noise, and speech with power-frequency interference), guiding students to contemplate technical pain points in TWS earphones, hearing aids, and related products. The theoretical segment establishes physical intuition for Fourier transforms through dynamic animations demonstrating spectral synthesis of square waves, with particular emphasis on the duality between time-domain convolution and frequency-domain multiplication, revealing the engineering value of FFT algorithms in reducing computational complexity from $O(N^2)$ to $O(N \log N)$.

The practice segment employs the simulation software, where student groups complete FFT transformation, spectral analysis, Butterworth/Chebyshev filter design, frequency-domain multiplicative filtering, and IFFT reconstruction of audio signals. Critical engineering decision points involve parameter trade-offs among passband ripple, stopband attenuation, and transition bandwidth- which directly correspond to the user experience balance between "noise reduction efficacy" and "speech fidelity" in entrepreneurial products. The innovation expansion segment introduces

technological evolution pathways including adaptive filtering, spectral subtraction, and deep learning-based noise reduction, using the AirPods Pro "feedforward + feedback" hybrid noise cancellation architecture as an exemplar to dissect the industrial logic of system-level innovation. Students complete creative proposals on the theme "If I were to design a noise reduction product for a specific scenario," with select outstanding works being transformed into projects for the "Internet+" Innovation and Entrepreneurship Competition.

3.2. Case 2: Wireless Sensor Network Data Acquisition System Based on the Sampling Theorem

This case corresponds to the chapter "Time-Domain Analysis of Discrete-Time Signals and Systems," focusing on the engineering application of the Nyquist sampling theorem^[8]. The scenario is set in chemical plant reactor monitoring, with the core conflict between battery supply constraints and monitoring effectiveness requirements. The theoretical segment not only elucidates the standard formulation $f_s \geq 2f_{max}$ but also reinterprets it from an entrepreneurial perspective: the sampling rate represents a baseline for "cost-performance" trade-offs rather than an absolute truth, with non-uniform sampling and compressive sensing representing innovation directions that transcend Nyquist limits.

The practice segment designs an adaptive dual-rate sampling algorithm: low sampling rate maintains monitoring during normal conditions, switching to high-resolution diagnostic mode upon detection of anomalous spectral features. Students must quantitatively analyze power consumption models, comprehending the ROI logic of investing \$2 in hardware costs (anti-aliasing filters) to achieve tenfold battery life extension. The innovation expansion introduces the case of German ifm electronic vibration sensors- whose innovation essence lies in performing FFT feature extraction at the sensor node rather than transmitting raw waveforms, reducing data volume by two orders of magnitude. This "edge intelligence" approach inspires students to contemplate lightweight entrepreneurial pathways of "hardware-end spectral analysis + cloud-based pattern recognition," effectively aligning with industrial Internet of Things demands.

3.3. Case 3: Autonomous Driving Millimeter-Wave Radar Signal Processing System Based on System Function Analysis

This case spans two chapters, which are "Time-Domain Analysis of Continuous-Time Systems" and "Frequency-Domain Analysis", with zero-pole analysis of the system function $H(s)$ as the core knowledge point. The scenario is anchored in the industrial context where L2+ autonomous driving penetration exceeds 40%, with urgent demand for domestic millimeter-wave radar substitution. The theoretical segment maps zero-pole positions to radar engineering parameters: pole positions correspond to resonant cavity center frequencies, zero positions enable notch filter design for co-channel interference suppression, and stability criteria directly relate to ISO 26262 functional safety certification requirements^[9].

The practice segment designs an intermediate-frequency signal processing chain for FMCW radar, with particular focus on completing the system function design of anti-

aliasing filters. Given authentic engineering constraints including intermediate-frequency bandwidth of 10 MHz and ADC sampling rate of 25 MHz, students must select among Butterworth, Chebyshev, and Elliptic approximation types, quantitatively analyzing trade-offs among passband ripple, transition bandwidth, and stopband attenuation. The innovation expansion dissects the technical trajectory of Israeli 4D radar unicorn Arbe Robotics, whose \$720 million valuation derives from real-time processing of ultra-large-scale MIMO system function matrices. Patent circumvention design tasks require students to comprehend the innovation methodology that "system function design space is infinite," cultivating intellectual property awareness for hard-tech entrepreneurship.

3.4. Case 4: Switched-Mode Power Supply Control System Based on Laplace Transform

This case corresponds to the chapter "Complex Frequency-Domain Analysis of Continuous-Time Systems," with Laplace transform and stability analysis as core knowledge points. Switched-mode power supplies constitute critical components in consumer electronics, electric vehicles, and data centers, with control loop design directly impacting system reliability. The theoretical segment commences from power-stage state equation derivation to establish transfer function models for Buck/Boost topologies, with particular emphasis on how compensation network zero-pole configuration affects phase margin and gain margin, revealing the eternal engineering conflict between "stability and dynamic response speed."

The practice segment employs the MATLAB/Simulink platform, where students complete power-stage modeling, voltage-mode control loop design, compensation network parameter calculation, and closed-loop system simulation. Phase margin is analyzed through Bode plots, dynamic response is verified through load transient simulation, and optimal design points are identified through parameter sweeps. The innovation expansion introduces technological trends including digital power supplies, adaptive control, and multi-phase interleaved parallel architectures, comparing technical trajectories of domestic and international vendors including TI, ADI, Silergy, and Southchip Semiconductor, thereby reinforcing industrial cognition and mission commitment regarding domestic substitution.

4. Instructional Outcomes and Assessment Reform

4.1. Multi-Dimensional Assessment System

Departing from single-mode written examinations, we establish a four-dimensional assessment system comprising "knowledge comprehension (30%), engineering implementation (40%), innovative thinking (20%), and teamwork (10%)." Knowledge comprehension is evaluated through conceptual testing; engineering implementation is quantitatively assessed through code quality, noise reduction metrics, and stability margins; innovative thinking is evaluated through technical feasibility reports focusing on scenario insight, differentiated positioning, and business model logic; teamwork is comprehensively evaluated through peer assessment within groups and presentation performance.

4.2. Outcome Analysis

Since implementing this model over two academic cycles, student course satisfaction has increased from 82% to 94%, with the excellence rate for laboratory reports improving by 18 percentage points. More significantly, transformative outcomes have emerged: the "adaptive noise reduction for sports scenarios" project derived from Case 1 received provincial-level funding under the Undergraduate Innovation and Entrepreneurship Training Program; the low-power sensing solution from Case 2 achieved second prize in the "Challenge Cup" competition; and the radar signal processing algorithm from Case 3 was adopted by an enterprise as a technical pre-research direction. These data demonstrate that PIE integration not only enhances learning experiences but also generates quantifiable innovative outputs.

5. Conclusion and Future Perspectives

The three-stage pedagogical model of "theoretical construction-engineering practice-innovation expansion" proposed in this paper, implemented through four representative teaching cases, achieves a profound transformation of the "Signals and Systems" course from "knowledge transmission" toward "competency cultivation" and "innovation enlightenment." The core experience resides in three principles: PIE integration is not about appending content but excavating inherent innovation and entrepreneurship genes within professional knowledge; it is not about instructor indoctrination but enabling students to autonomously discover innovation spaces within authentic engineering constraints; and it is not about isolated courses but constructing ecosystems aligned with competitions, projects, and industries.

References

- [1] Hu D X, Guo H C. The Layout, Characteristics and Trends of First-class Undergraduate Course Construction under the Background of New Engineering [J]. Journal of Ningbo University (Educational Science Edition), 2025, 47(05): 12-23.
- [2] The Ministry of Education Holds an Inter-Ministerial Working Conference on Supporting College Students' Innovation and Entrepreneurship[J]. China University Students' Employment, 2021,(23):33.
- [3] Zheng J L, Ying Q H, Yang W L. Signals and Systems (3rd Edition) [M]. Beijing: Higher Education Press, 2011.
- [4] Oppenheim A V, Willsky A S. Signals and Systems (2nd Edition) [M]. Upper Saddle River: Prentice Hall, 1997.
- [5] Fu M X, Duan Y, Yang L S, et al. Reflections and Explorations on Industry-Education Integration Model for Electronic Information Majors under the Background of New Engineering Education[J]. Journal of Higher Education, 2023, 9(31):87-90.
- [6] Hou L. Teaching Reform of the Signals and Systems Course Based on the OBE-CDIO Concept [J]. Education and Teaching Forum, 2025, (45): 61-64.
- [7] Liu C, et al. Research on Pathways for Deep Integration of Innovation-Entrepreneurship Education and Professional Education [J]. China Higher Education Research, 2021(8): 92-98.
- [8] Shi Y C, Huang X Y. Integration Path of Professional Education and Innovation and Entrepreneurship Education in American Universities: Based on Multi-Case Analysis[J].

Research in Higher Engineering Education, 2024, (06): 193-200.

[9] ISO 26262. Geneva: International Organization for Standardization, 2018.