

Research on Innovation of AI-Assisted Classroom Teaching Mode in Communication Electronic Circuits

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Abstract: The communication electronic circuits feature includes high-frequency signal processing and multi-module coupling, which has non-linear cognitive load distribution in classroom teaching with inherent shortcomings when using traditional lectures to solve break points in deductive logic or no immediate feedback. Taking an artificial intelligence assistance perspective according to analyzing the mapping relationship between the course's knowledge structure and students' cognitive load, we defined the functional position and technical boundary of artificial intelligence, built a behavioral sequence based cognitive diagnosis model, a parameterized deduction intervention strategy, and a multimodal learning-state fusion mechanism, providing optimization path including completion of logical chain breaks, generative topological mutation prompts, and personalization content reorganization. Our research tries to provide a reference analytical framework and implementation ideas on human-machine collaboration teaching for high-frequency electronic circuit courses.

Keywords: artificial intelligence-assisted teaching; Communication Electronic Circuits; cognitive diagnosis; behavioral sequence analysis; classroom teaching model

Introduction

The Communication Electronic Circuits course cultivates the skill of analyzing high-frequency signals and designing RF circuits. Functional modules (resonant circuits, mixers, oscillators, phase-locked loops), which are closely connected by frequency conversion and impedance matching, have a lot of cognitive tasks running simultaneously: complex number operation, frequency domain transformation, topological abstraction; The cognitive load is non-linearly distributed. The traditional teaching approach using blackboard writing and slides gradually attenuated with delayed feedback transmission of high-density information. Although there could be technical support from artificial intelligence for real-time perception of learning state, visualization of deduction and content adaptation, it does not have special assistance strategy targeting towards the Knowledge Structure of Communication Electronic Circuits. In our study we focus on issues like cognitive load distribution, feedback latency and break in deductive logic, explore the functional position, interaction mechanism, and optimization path of artificial intelligence to provide theoretical references and methodological frameworks for innovations in course teaching models.

1. Teaching Characteristics of the Communication Electronic Circuits Course and the Applicability of Artificial Intelligence Empowerment

1.1 Knowledge Structure of the Communication Electronic Circuits Course and Its Nonlinear Cognitive Load Characteristics

The transmission and processing of high frequency signals is the main thread for the Knowledge System of the Communication Electronic Circuits course: its core functional modules include resonant circuits, power amplifiers, mixers, oscillators and phase-locked loops which are closely connected through basic theories (frequency conversion, impedance matching, feedback control), whose understanding relies upon a good grasp of prerequisites; three kinds of simultaneous thinking activities with different nature – symbolically computing, deducing waveforms, and topologically abstracting greatly increase the rate of working memory consumption due to resource competition between multiple cognitive channels. Deriving the gain-bandwidth product of high-frequency small-signal tuned amplifiers or judging the start-up condition of an oscillator usually become bottlenecks in

understanding because it needs multiple abstract operations (complex number operations, logarithmic coordinate transformation and time-frequency domain conversion) to be handled simultaneously. Nonlinear features of this compound deduction lead to accumulation of cognitive load at some nodes of the knowledge graph.

According to the above characteristics, instructional design should find out the peak area of cognitive load in the knowledge graph and target decomposition, decomposing compound deduction into individual cognitive unit for processing. The sequential dependency in the knowledge structure requires teachers to check whether the student has retained the concept as a prerequisite when teaching new content so that the subsequent teaching can be conducted upon an unstable cognitive foundation; Organization of teaching activities need to consider reducing the occupation of working memory in cross-concept deduction: Before teaching image interference in mixers we must make sure that the students already clearly understand the mapping relationship between the receiver front-end selectivity curve with the shape of the intermediate frequency filter. Arrangement according to cognitive load diagnosis increases the effectiveness of information transmission without compressing course capacity^[1].

1.2 Information Attenuation and the Absence of Immediate Feedback in the Traditional Lecture Model

The traditional teaching methods of Communication Electronic Circuits in class mostly use derivation from the blackboard and slides presentation for the main teaching method. The information passes level by level through the chain: teacher's expression - media transmission - student reception - internalization. All kinds of attenuations occur at different levels. For example when drawing the AC equivalent circuit of a tuned amplifier on the blackboard, students must copy it, match the symbol, and understand its function; if any label is ambiguous or corresponded incorrectly then the next step (frequency response) analysis will lose a solid starting point. Another type of attenuation occurs due to logical gaps between concepts. Students may memorize the shape of the resonance curve and the selectivity index without being able to automatically derive an inverse relationship between the Q factor and bandwidth. These cumulative effects of logical gaps has a superimposed characteristic as the course proceeds^[2].

Lack of immediate feedback: Mistakes made by students while deriving gain expression of a mixer or computing the frequency stability of an oscillator are of great diagnostic significance which can be acquired from the teacher only after grading homework or doing periodic tests. No chance for the feedback to rectify the learning process that has taken place. Asking questions during class may help; however it covers only a small sample because of time limits and understanding state of most students is hidden. Teacher keeps on teaching as per the preset schedule without knowing who are still lingering in analyzing nonlinear distortion or who have developed conceptual confusion regarding the stability judgment of feedback amplifiers. Latency of feedback leads to accumulation of mismatch between teaching content and learners' cognitive states.

1.3 Functional Positioning and Technical Boundaries of Artificial Intelligence in Communication Electronic Circuits Teaching

Although Artificial Intelligence cannot replace teacher's judgment for teaching Communication Electronic Circuits in the classroom, but it helps teachers observe and respond to micro-dynamics inside classrooms. The main functions are as follows: Real-time collection and organized presentation of learning state data enabling teachers to have a quantitative picture of the whole class's cognitive states during instruction; Interactive visualization of the deduction process, dynamic display of causal relationship between abstract network functions and physical waveforms with adjustable parameters; Intelligent mapping of conceptual association tracing the weak link in students' prerequisite knowledge if there exists a deviation on a certain knowledge point. All these help teachers make decisions instead of replacing them whose outputs need to be filtered by teachers' teaching experience so that they could turn into effective teaching behaviors.

Shortcomings of current artificial intelligence needs explanation: Rigorous mathematical derivation and symbolic logic processing in Communication Electronic Circuits exceeds the capability of existing models; Accuracy of large language model's complex-domain operation and differential equation solving does not meet the requirement of rigor in classroom instruction. Circuit fault diagnosis and parameter optimization is an optimization problem under multivariable constraints whose solution is

given by artificial intelligence as a heuristic reference instead of a standard answer (decision-making power belongs to teachers); System latency limitation, misjudgment rate, training data coverage all demand keeping manual intervention interface in classroom applications so that the abnormal output of the auxiliary system will not interfere with the normal teaching order. Clearing out technical boundary is the precondition for going from concept to effective application^[3].

2. Dynamic Interaction Mechanism of AI-Assisted Classroom Teaching in Communication Electronic Circuits

2.1 Cognitive Diagnosis Model of Circuit Concepts Based on Learning Behavior Sequences

Each drag of components, change of parameters, and waveforms observation command when communicating in a Communication Electronic Circuits classroom using an interactive simulator or electronic whiteboard system represents one time step for a behavioral sequence corresponding to the current understanding state of learners' circuit concepts; the AI-assisted system converts its operation sequence into a state vector including node voltage selection preference, component parameter adjustment step size, and switching frequency from waveform observation perspective. Temporally modeling the sequence data via a long short-term memory network, it could infer the specific cognitive level (remembering, understanding, applying, analyzing) without interrupting the operation process. If the repeated trial-and-error pattern at a certain concept node exceeds a preset tolerance threshold, then the model will output a diagnostic marker that triggers a concept backtracking prompt. This diagnostic method based on dynamic behavioral flow instead of static test results is close to the real operating state of the classroom.

The advantage of the cognitive diagnosis model is to differentiate different types of errors and its root cause: e.g., when a student keeps deviating from the center frequency while adjusting the load curve of a tuned amplifier, it might be due to him/her making an error about remembering the resonance condition calculation formula; or misunderstanding that there exists an inverse relation between the quality factor and the passband. We compare the deviation distance and direction with the preset typical correct path to categorize this type of error as calculation errors, conceptual confusion or inappropriate strategies and show them visually on the teacher terminal. The temporal resolution of the diagnostic result is at the minute level which allows teachers to get the overall distribution of concept mastery in the class without waiting for after-class homework and adjust the emphasis and speed of next instruction accordingly^[4].

2.2 Parameterized Presentation of the Deduction Process and Immediate Intervention Strategies for Misconceptions

Many phenomena in Communication Electronic Circuits need to understand through changing parameters and observe their effect -- which cannot be shown via traditional slides. By using an AI platform, we build a digital twin model of an active load resonant amplifier circuit. Changing bias resistor or feedback capacitor will refresh the amplitude-frequency characteristic curve and signal wave simultaneously that links up the network function expression with its visualization for presentation. Parametric presentation approach brings advantages transforming the abstract complex number operations and frequency domain transformation into operable causal chains: students intuitively link between the location of poles and zeros to the frequency response by drag a slider to see how the resonant peak moves (less relying on pure math derivations).

In terms of design of strategic immediate intervention for misconceptions, there are two key variables including intervention timing and intervention method. If the system finds that a student pushes a certain parameter to an extreme value such that the circuit enters into the nonlinear distortion region, rather than give out the correct setting value or judge its operation as erroneous immediately, we will generate an overlay comparison view between the normal output curve with adjacent parameters vs. the current distortion curve, leading students to find out the reason for their deviation on their own. Advantage of this kind of contrast-driven intervention strategy lies in keeping learners' space for active thinking without the shallow memory effect due to passive acceptance of the correct answer. For intervention timing selection, system triggers intervention if the student repeatedly deviated from the correct trajectory multiple times and confidence score keeps declining but no prompt will trigger for one accidental deviation. Threshold control mechanism balances both necessaryness and frequency rationality of instructional intervention.

2.3 Real-Time Classroom Fusion of Multimodal Learning-State Data and Teaching Pace Regulation

Learning state signal acquisition on the Communication Electronic Circuits classroom changed from just the homework accuracy rate to multi-source heterogeneous data (response time distribution in in-class quizzes, frequency of parameter modification in interactive simulators, self-reported understanding level annotations). Usually, the single source information is one-sided. We use dynamic weighting with an attention mechanism for different modalities as an effective snapshot of the whole class's cognitive states within fifteen minutes after the start of the class. Weighting basis is derived by the statistics of the predictive validity of each modality about examination scores in previous classes; if the response time distribution has a higher indicative value than the self-assessment data concerning concept proficiency, we will increase the fusion weight of the time dimension so that our comprehensive judgment can be closer to the true state^[5].

Implementation Path for Teaching Pace Regulation According to Comparison Logic Between Fused Data and Preset Schedule: compares the current probability of class-wide understanding deviation vs. the theoretical pass-rate threshold of its corresponding node in the course knowledge graph in real-time, if it exceeds the set threshold, send pace-adjustment signal from the system to the teacher terminal together with the recommended increment in dwell time; the teacher decides whether to add demonstration of intermediate-state deduction or supplement a set of simulation cases of extreme operating conditions based upon his own professional judgment (the system only gives data support); when giving pace-adjustment suggestions, taking into account not only the remaining course time but also the volume of untaught content to avoid excessive adjustments leading to content compression at the end of the term, achieve a sustainable balance state between classroom advancement speed and the cognitive absorption rate of the student group.

3. Optimization Paths for the Effectiveness of AI-Assisted Classroom Teaching in Communication Electronic Circuits

3.1 Identification of Logical Chain Breaks in Circuit Deduction and Intelligent Completion Mechanism

The deduction obstacles encountered by students in the Communication Electronic Circuits classroom generally come from memorizing single design formulas/test metrics but not establishing a full causal chain for signal processing. In traditional lecture mode, teachers ask students one by one; there is an obvious limitation with regard to coverage and timeliness. Our AI-assisted system builds a hierarchical knowledge graph oriented to communication links that annotate the strength of derivative dependencies and types of prerequisites between nodes. If students skip any necessary constraint conditions when they design their parameters, our system will precisely point out the logical gap via highlighting missing nodes in a visualized topology. The functional positioning of this completion module focuses on restoring structure integrity instead of giving correct answers, aiming at prompting students to build up full-chain causal awareness from input to output^[6].

Breaks are identified via quantification of operation jump degree within an interactive simulator: if the system finds out that students skip the derivation steps of Q-factor changes by directly measuring the passband width upon changing the load resistance of the resonant amplifier then the cognitive jump is over the tolerance threshold triggering the activation of the completion module showing the skipped derivation substeps in a collapsible panel for independent expansion and viewing; whereas for other kinds of hidden breaks (e.g., completing all calculation steps with using a mismatched prerequisite formula), we will mark conflict points between the applicable conditions of the formula against the current circuit topology via graph dependency matching verification so as to block the erroneous reasoning path at its source during continued use.

3.2 Circuit Topology Variation and Constraint Satisfaction Prompts Based on Generative Reasoning

Design Problems in Communication Electronic Circuits typically have many topologies meet required performances as solutions. A unique standard solution is provided by teachers during class teaching without being aware about the openness of the design space. With generative models, our AI-assisted system generates different feasible circuit's structure variants satisfying the constraints of gain, noise figure, and power consumption; show the performance trade-off distributions of cascode structures, cascade structures, and source-degeneration structures, respectively, for low-noise amplifiers.

Our system doesn't identify which is best but for each topology, highlight the specific node position meeting standards or exceeding boundaries. One variant meets the requirement for noise figure but exceeds the boundary on the stability circle, then students need to do quantitative trade-offs between multiple objectives.

We overlay the constraint satisfaction status on top of the circuit schematic with a heat map (qualified nodes, out-of-bound nodes and critical nodes). By clicking an out-of-bound node we can see how much that particular deviation deviates from its upper constraint limit. Data about students' tendency for selecting multiple topology schemes will also be recorded at the same time. If a student always selects high gain schemes and ignores stability constraints all the time, our system triggers targeted material delivery regarding stability compensation techniques. Our output of generative reasoning not only assists in class designs, it provides follow-up learning guidance too.

3.3 Dynamic Reorganization of Teaching Content and Strategies for Generating Personalized Learning Paths

The difficulty faced by studying Communication Electronic Circuits differs widely across people: some get stuck on analyzing the oscillator frequency stability but other becomes stuck calculating mixer interference rejection ratio. Very difficult to keep a common speed which can satisfy both different needs. Dynamic adjustment to the presentation sequence and depth distribution of teaching contents based upon the performance feature vectors derived from previous interaction with the help of the AI. If they have mastered the transmission line theory, then simplify the derivation steps; if they are not good at operating Smith charts, we add more impedance matching exercises. The direct basis of generating paths is calculated results of the matching degree between their current knowledge state vector and prerequisites required for each node in the course knowledge graph. If it is lower than the threshold, insert preparation supplementary content or else advance normally.

Limitation exists for dynamic reorganization; it cannot damage the integrity of course structure after personal adjustment. Coverage verification is used at every path reorganization to ensure the adjusted sequence covers all core knowledge units stipulated by the syllabus and if too much trimming causes missing of mandatory concepts, then the system will revert/reduce the scope of reorganization automatically. The path generation respects the logical order of adjacent chapters without untaught modulation theory caused by a student's current preference (to avoid new cognitive confusion induced by cross-level dependencies). Constrained personalized paths make classroom teaching become a self-organizing process adapting to individual differences with the system's regulation being always restricted by the logical constraints of the course knowledge system itself.

Conclusion

Three issues concerning the nonlinearly distributed cognitive load, breaks in deductive logic, and delayed identification of group-wide understanding deviations are tackled for teaching Communication Electronic Circuits in the classroom; construct an AI-assisted teaching framework with perception of learning states, dynamic interaction, and path optimization at different levels. Clarify the auxiliary position and technical boundaries of our system (the essence is improving teachers' capability to perceive micro-level classroom dynamics) at the level of applicability, establish a behavioral sequence-based cognitive diagnosis model, a parameterized deduction intervention strategy, and a multimodal data fusion method to achieve the transition from delayed to near-real-time feedback, and design logical chain break completion, generative topological mutation prompts, and constrained personalized path generation methods to expand the range of assistance from one point to systematic support. Our study proves that using artificial intelligence needs the logic of the course knowledge graph as the constraint boundary while its system output should be interpreted by teachers professionally so it can become effective teaching behavior. In future works, we may have deeper exploration such as cross-course transfer of diagnostic models, controllability of generative topology, quantification of teachers' subjective evaluation signals, and cognitively-friendly design of human-machine interface interactions, promoting the in-depth development of AI-assisted teaching towards discipline-specific scenarios.

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