

Reform and Practice of "Capability-Targeted" Algorithm Analysis and Design Course Based on Deep Learning

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Abstract

This paper focuses on the teaching reform of the "Algorithm Analysis and Design" course, proposing a competency-targeted teaching model in conjunction with deep learning technology. Based on AE dimensionality reduction and K-means, an intelligent learning situation analysis model is designed. The teaching content is reconstructed in a tiered manner, and a targeted teaching method is innovatively proposed relying on a dynamic difficulty adjustment mechanism. Additionally, a diversified assessment method is innovated to comprehensively assess students' abilities. Practice has shown that this model significantly enhances students' algorithm design capabilities and engineering practice literacy, providing a replicable path for the reform of computer science courses in the intelligent era.

Keywords

Algorithm analysis and design; intelligent learning situation analysis; ability-targeted; teaching reform.

1. Introduction

In the context of "New Engineering" education, the curriculum system and teaching methods of engineering majors place greater emphasis on practicality, interdisciplinarity, and comprehensiveness. The cultivation of engineering talents focuses more on enhancing students' practical abilities, innovation capabilities, comprehensive application abilities, and overall professional qualities. Algorithm analysis and design is one of the courses in computer science that is most closely related to practical engineering problems. It requires a theoretical foundation and full integration with practical applications to cultivate students' ability to solve engineering challenges, meeting the requirements of "New Engineering" for the cultivation of applied talents in terms of engineering innovation and adaptability to change^[1]. Through the study of this course, students will not only grasp the working principles of current major algorithm technologies but also understand the background and design philosophy behind these algorithms, enabling them to flexibly apply these technologies and design appropriate algorithms to solve problems in practical situations.

2. Current Status of Course Teaching

In the computer science and technology major at Shaanxi International Business and Trade College, the "Algorithm Analysis and Design" course is taught in the sixth semester. At this stage, students have already acquired certain computer professional competencies, but their learning abilities vary greatly, and there are still differences in students' cognitive abilities and interest orientations, posing challenges to personalized education in the course. The current teaching of the course faces the following difficulties:

2.1. Lack of objectivity and intelligence in grasping learning situations

Traditional learning situation analysis has certain limitations and lacks objective and intelligent analysis. Firstly, the analysis process is highly subjective, with teachers easily labeling learners based on their own experiences. Secondly, traditional questionnaire surveys struggle to capture students' cognitive states in real-time, leading to a lack of data support for adjusting teaching strategies. Thirdly, the analysis results are mostly targeted at the entire class rather than individual learners, thus failing to reflect individual differences^[2].

2.2. The organization of teaching content lacks vertical and horizontal connections

From a longitudinal perspective, although the teaching content includes introductions to various algorithms, the presentation of various concepts does not follow a gradual cognitive path from concrete to abstract and from simple to complex. From a horizontal perspective, there is a lack of meaningful connections between knowledge points, and there is a gap between textbook cases and industrial-level algorithm implementations, lacking a gradual connection from basic theory to engineering application. This significantly affects students' knowledge construction efficiency and learning experience.

2.3. Simplification of teaching methods

Currently, the teaching of this course primarily relies on lectures given by teachers. Within the same class, students have vastly different cognitive maps. The traditional classroom model inhibits students' initiative to explore, resulting in insufficient training in algorithm design skills in the classroom.

2.4. One-sided evaluation dimensions

The traditional course assessment method relies too heavily on final exams and lacks sufficient evaluation of process-oriented abilities, making it difficult to comprehensively reflect the development trajectory of students' algorithmic thinking. Furthermore, it lacks evaluation of ideological and political literacy.

Effectively identifying the difficulties in teaching and finding suitable solutions for each learning style through reconstructing teaching content, applying flexible teaching methods, utilizing diverse evaluation methods, and providing resource support are urgent issues that need to be addressed for this course.

3. Teaching Reform Measures

The course on algorithm analysis and design plays a pivotal role in cultivating students' computational thinking, problem-solving abilities, and algorithm design and innovation capabilities. With mathematical modeling, complexity analysis, and algorithm design and optimization as its core, this course serves as both the theoretical foundation for subsequent professional courses and the technical cornerstone for emerging fields such as artificial intelligence and machine learning. Therefore, teaching reforms should be implemented in the following aspects to enhance teaching effectiveness.

3.1. Build an intelligent learning situation analysis model

Construct an intelligent learning situation analysis model based on the K-means clustering algorithm^[3] developed through machine learning. The model consists of four parts: multimodal data acquisition module, data preprocessing module, clustering analysis model, and evaluation model, as shown in Figure 1.

The multimodal data collection module primarily gathers different types of data from three temporal dimensions: before class, during class, and after class. Before class mainly includes

preview status and associated course grades. Preview status includes login duration on online learning platforms, quiz scores, etc., while associated courses mainly refer to students' grades in associated course learning. During class, it records classroom participation data such as attendance rate, number of speeches, discussion activity, and in-class quiz scores, reflecting real-time learning status. After class covers achievement indicators such as homework completion quality, experiment report scores, and competition awards.

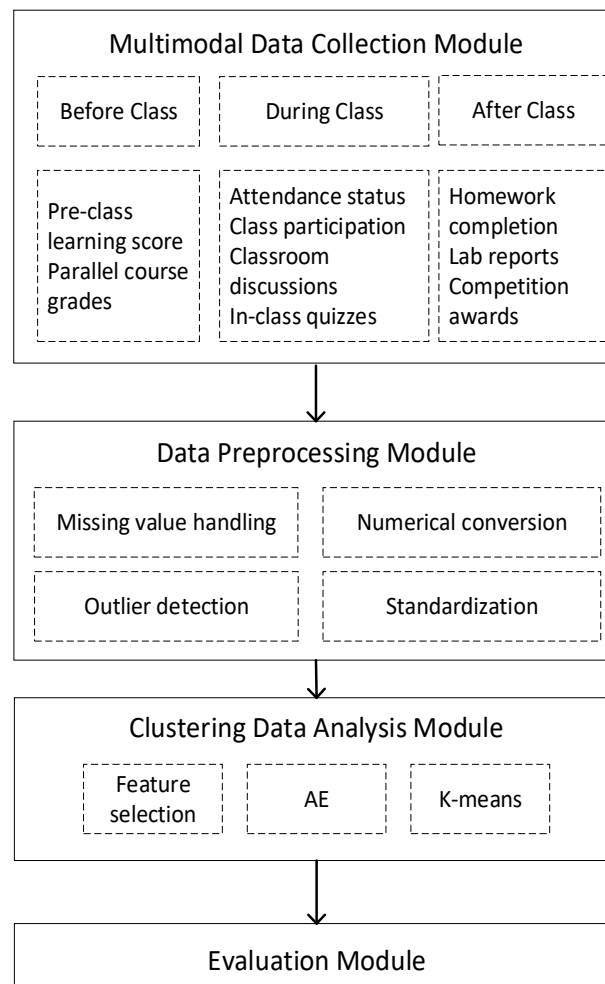


Figure 1. Intelligent learning situation analysis model

Due to the presence of noise and heterogeneity issues in the raw data, data preprocessing is required. Data preprocessing module mainly includes the following four aspects: handling missing values, deleting or filling in missing indicators, such as completing absentee records with the mean value. Numericalization involves converting non-numerical data, such as classroom participation ratings of "active/general," into numerical values of 1/0. Outlier detection involves removing obviously unreasonable data, such as a student who gets a perfect score on a single test but has extremely low grades in regular exams. Standardization eliminates the influence of dimensionality, such as uniformly scaling attendance rates (0-100%) and test scores (0-10 points).

The clustering data analysis module filters key features through feature selection, then compresses high-dimensional data using an autoencoder (Autoencoder) to retain effective features through AE dimensionality reduction, and finally discovers student group characteristics through K-means clustering, clustering students with similar characteristics into four categories: "Active", "Passive", "Subject-biased", and "Potential".

To verify the clustering effect, the model includes evaluating the clustering results through internal and external indicators and tuning the model.

The Intelligent learning situation analysis model can comprehensively depict learning behaviors, provide favorable support for personalized targeted teaching, offer quantitative basis for teaching, and assist in optimizing teaching strategies.

3.2. Reconstruct ladder-style teaching content

The principle of "cognitive spiral progression" reconstructs the ladder-style teaching content, breaking down complex algorithmic knowledge into hierarchical and progressive ability modules. Each ladder consists of: the foundation layer (memory comprehension) → the application layer (practical verification) → the innovation layer (transfer and expansion). It is accompanied by practice tasks and progressive challenge tasks with appropriate difficulty levels.

Hierarchical reconstruction of knowledge system

Table 1. Example of knowledge system hierarchy

Hierarchy Level	Teaching Objectives	Typical Content	Teaching Methods
Basic Principles Layer	Understand basic algorithm concepts and processes	Pseudocode description of sorting algorithms, definition of time complexity	Analogical explanation
Design & Analysis Layer	Implement classical algorithms and analyze their pros and cons	Handwritten quicksort code, comparing performance differences with bubble sort	Code experiments + performance testing
Optimization & Design Layer	Optimize algorithms to solve practical problems	Optimizing merge sort for specific data characteristics	Project-driven learning
Comprehensive Application Layer	Design new algorithms or combined applications	Combining DFS and greedy algorithms to solve real-world path planning problems	Academic competitions

Through the hierarchical reconstruction of knowledge, as shown in Table 1, the teaching content can be aligned with the "Pyramid Principle", facilitating the transition from "information accumulation" to "thought flow".

(2) Advanced reconstruction of practical projects

Reconstruct the content of practical projects based on the idea of advancing according to difficulty, and design experimental projects in three categories: foundation, strategy analysis, and synthesis, gradually increasing difficulty and challenge. The following is a hierarchical design plan for advancing experiments:

The basic verification layer, with a relatively easy difficulty, aims to enable students to understand the basic principles of algorithms, such as the coin change problem using greedy algorithms. The basic experiments mainly verify the effectiveness of greedy algorithms under different currency systems, and design counterexamples to prove non-global optimal situations. The strategy analysis layer, with a moderate difficulty level, aims to enable students to master the strategy design of algorithms. For example, in the greedy algorithm for the knapsack

problem, the experiment focuses on comparing the benefit curves of different strategies by visualizing the three greedy strategies: value density, weight, and value.

The comprehensive application layer poses a higher level of difficulty, aiming to enable students to comprehensively apply various algorithms to solve complex real-world problems. For instance, it involves addressing wireless network channel allocation issues, devising greedy strategies under time-varying conditions, and considering future predictive improvements to greedy algorithms.

Among the three-tier practical tasks, basic verification and strategy analysis are mandatory for each student, while the comprehensive application tier can be completed through group collaboration and division of labor. This kind of practical teaching project, reconstructed based on difficulty levels, allows students to learn step by step, facilitates teachers in assigning tasks according to different levels, and makes project maintenance and functional expansion easier, thus making performance optimization more targeted.

3.3. Innovative Capability-Targeted Teaching Method

The classroom innovation explores targeted teaching methods. In the learning situation analysis stage, it accurately analyzes student types through intelligent learning situation analysis, identifying precise targets for targeted teaching. In the teaching content reconstruction stage, it reconstructs the teaching content through hierarchical design of the knowledge system and advanced practical projects, separating the teaching content into fine granularity to accurately match the targets for targeted teaching. The Capability-Targeted Teaching Method is illustrated in Figure 2.

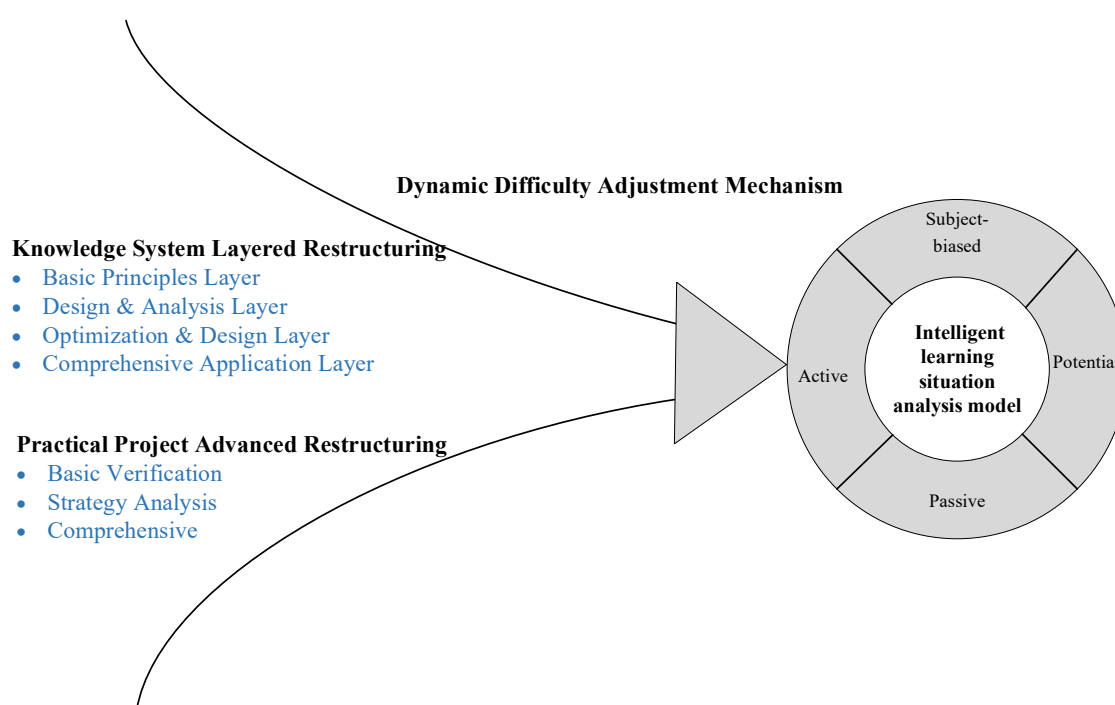


Figure 2. Capability-Targeted Teaching Method

The practical teaching of targeted teaching methods relies on a dynamic difficulty adjustment mechanism to implement precise individualized instruction. Intelligent learning situation analysis determines student types, and relies on advanced practical projects to construct a flexible task pool. The basic verification experiments and strategy analysis experiments in the flexible task pool must be 100% qualified for each student. If not qualified, consolidation training is repeated until qualified. After qualification, comprehensive application experiments

can be carried out. The comprehensive application experiments are conducted in groups, with role assignments based on students' interest areas and strengths. This allows for flexible adjustment of the tasks students need to complete and the abilities they need to exercise. Through structured collaboration, responsibility-driven approach, and differentiated task allocation, it effectively enhances students' teamwork ability, learning initiative, and practical skills. It not only optimizes the experimental process but also makes the classroom closer to real scientific research or work scenarios.

3.4. Innovate diversified assessment methods

To comprehensively assess students' abilities, the curriculum implements a diversified assessment mechanism tailored to different student levels. The reform of diversified assessment should be based on the principle of individualized instruction, establish a multi-dimensional evaluation system, and fully consider students' individual differences and development potential.

The assessment focuses on the tracking evaluation of the learning process and adopts a composite form of "regular assessment + experiment + final examination", with regular assessment accounting for 20%, experiment accounting for 20%, and final examination accounting for 60%.

The assessment primarily focuses on mastering basic knowledge and assessing changes in learning attitude through a combination of "classroom performance, regular homework, and periodic quizzes". Weekly knowledge mastery tests are conducted, with three make-up opportunities allowed, and an elastic scoring strategy of "counting the highest score" is adopted. In the practical assessment, a gradient experimental assessment system consisting of "basic experiments (50%) + strategic analytical experiments (30%) + comprehensive experiments (20%)" is established. Among them, the comprehensive experiments follow a three-stage evaluation process: "independent proposition-proposal defense-results presentation".

This stratified and diversified assessment system not only maintains the fairness baseline of basic education, but also provides differentiated development pathways for various students. It can effectively stimulate the learning motivation of students at different levels, achieve a paradigm shift from "one-size-fits-all" evaluation to "personalized development" evaluation, and form a virtuous cycle of teaching evaluation ecosystem.

4. Summary and Outlook

The algorithm analysis and design course serves as a cognitive bridge for students, connecting mathematical theory with computer implementation and cultivating their ability to transform abstract problems into concrete solutions. It is also a hub of competencies, serving as a general carrier of skills in emerging fields such as artificial intelligence, big data, and blockchain.

The competency-targeted teaching reform based on deep learning centers around layered teaching design and precise intelligent analysis of learning situations. It has established a project-driven personalized teaching model, significantly enhancing teaching efficiency and learning outcomes. Through the reform, the pass rate of students' courses has increased by 10%, and students have achieved excellent results in various national academic competitions. In the future, we will further integrate intelligent science theories, optimize the tiered and layered teaching content, and explore the application of virtual reality technology in tiered teaching, continuously promoting the effective integration of intelligent education in curriculum reform.

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