Frontiers in Computing and Intelligent Systems
ISSN: 2832-6024 | Vol. 12, No. 1, 2025

Algorithm Design and Experimental Research on Achievement Analysis of Output Oriented Course Objectives, Using Digital "Signal Processing A" as a Case Study

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Abstract: In the context of the deepening implementation of the principles of Output-oriented Education (OBE) in engineering education, the analysis of course goal achievement plays a crucial role in enhancing teaching quality. Aiming at the shortcomings of traditional analytical methods in modeling assessment indicators and diagnosing teaching improvements, this study constructs an analysis system for course goal achievement that integrates the Analytic Hierarchy Process (AHP), weighted comprehensive evaluation models, and data visualization techniques. This research scientifically quantifies the weights of assessment indicators by using AHP. It establishes a nonlinear weighted comprehensive evaluation model to depict the relationships among dimensions such as "theoretical knowledge" and "practical skills", breaking through the independence assumption of traditional linear models. Additionally, it designs a structured processing workflow for multi-source performance data. By integrating multidimensional data from regular performance, final assessments, and extension training according to their weights, it forms a quantitative calculation framework for the achievement of sub-goals and overall goals. Moreover, a data visualization module is developed to intuitively present the achievement status of each goal and individual student differences through bar charts, scatter plots, etc. Taking the teaching data of 116 students in the course "Digital Signal Processing A" at North China University of Science and Technology as a sample, the effectiveness of this system in quantitatively evaluating Course Goal 1 (achievement degree of 0.73), Goal 2 (achievement degree of 0.73), and Goal 3 (achievement degree of 0.72) has been verified. The relevant results provide data support for optimizing teaching content (such as enhancing the integration of theory and practice) and personalized guidance (such as focusing on students with weaker performance). Practice shows that the system provides a replicable technical solution for the assessment of course goal achievement in colleges and universities through the closed-loop design of "indicator weighting--achievement calculation--visual feedback". Its data-driven precision diagnosis mechanism can effectively contribute to the implementation of OBE and the continuous improvement goal under the concept of "student-centered".

Keywords: Output-oriented Education; Course Goal Achievement; Analytic Hierarchy Process; Weighted Comprehensive Evaluation Model; Data Mining.

1. Introduction

With the comprehensive implementation of the "China Engineering Education Professional Accreditation Standards" and the continuous improvement of talent cultivation quality requirements in the "Double First-Class" initiative, the Outcomes-Based Education (OBE) philosophy of "student-centered, outcome-oriented, and continuously improving" has taken a central role in university course development and evaluation.

The assessment of course goal achievement is crucial for implementing the OBE philosophy, aiming to establish a close connection between course goals and graduation requirements, achieve a scientific mapping of assessment data to goal attainment, and ensure effective interaction between evaluation results and teaching improvements.

However, universities currently face numerous challenges in evaluating the achievement of course objectives.

On one hand, traditional assessment methods often use linear weighted models, which assume that evaluation indicators are independent of each other. This severely overlooks the complex nonlinear relationships between dimensions such as "the mastery of theoretical knowledge" and "the cultivation of practical skills," leading to systematic biases in achievement calculations.

For example, in actual teaching, a solid foundation in theory often promotes the improvement of practical skills, while rich practical experience also helps deepen the understanding of theoretical knowledge. However, linear models fail to capture these interrelationships.

On the other hand, suggestions for teaching improvement mainly rely on teachers' personal experience and judgment, lacking data-driven diagnostic tools that can accurately identify issues in the teaching process and propose targeted improvements.

In response to the aforementioned issues, this study leverages data intelligence technology to construct an auxiliary system that encompasses data governance, intelligent evaluation, and dynamic feedback.

In terms of technical approach, it breaks free from the constraints of traditional linear models by introducing machine learning algorithms to effectively model nonlinear relationships between assessment indicators; in terms of implementation approach, it integrates multi-source data processing technologies to form an automated data processing and analysis workflow; in terms of application approach, it validates the system's effectiveness through empirical analysis of actual courses, providing a practical technical solution for the implementation of OBE concepts, aiming to enhance teaching quality in higher education institutions.

2. Core Technology Architecture and Implementation of the System

2.1. Construction of Hierarchical Structure Model

In the analysis of course goal achievement, this study uses analytic hierarchy process to construct a hierarchical structure model, which is divided into target layer, criterion layer and scheme layer.

The target layer is the achievement of course objectives. It is the overall goal of the realization of course teaching expectations, reflecting the comprehensive level that students should achieve in terms of knowledge, skills and literacy, and is an important indicator for course design and subsequent analysis and evaluation. The criterion layer includes assessment items that significantly impact the achievement of course objectives, comprising regular performance, final performance, and extension training.

Regular performance is used to evaluate students' enthusiasm in the learning process; extension training assesses the application of skills during course learning; final performance evaluates students' comprehensive knowledge level after the course concludes. These three assessment items evaluate students' learning qualities from different perspectives.

The scheme layer is composed of the specific students' scores: including chapter test scores, homework scores, sign-in scores, in-class performance scores, extension training scores, final performance scores and extension training scores.

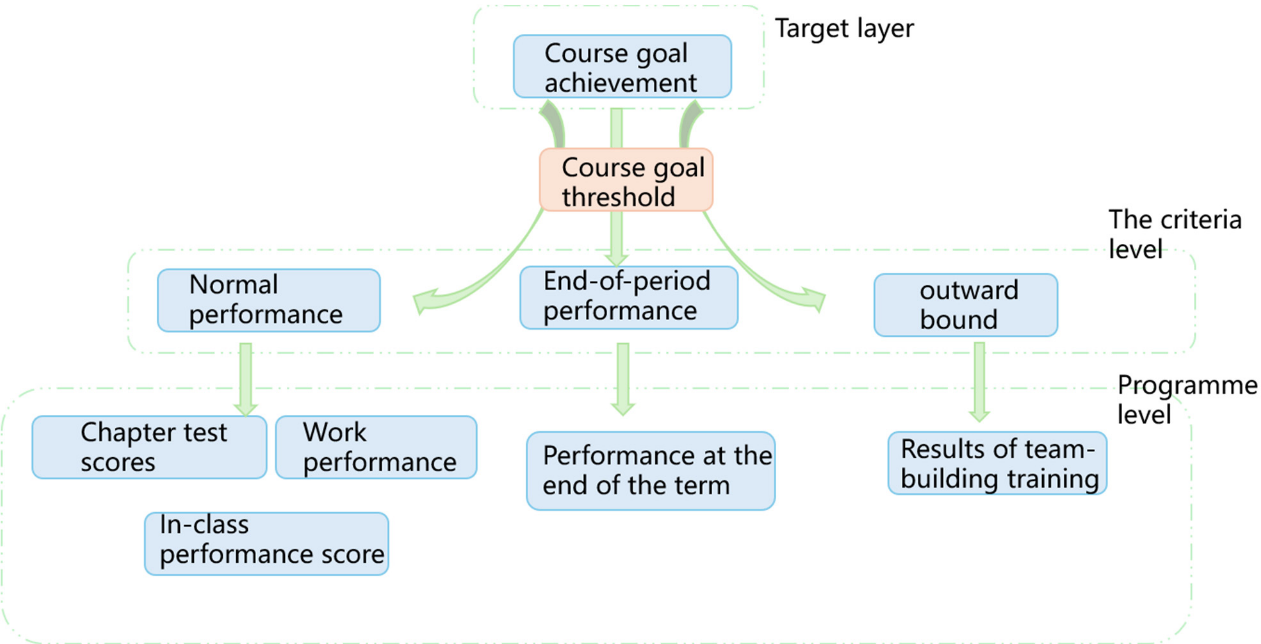

Figure 1. Hierarchical Structure of Course Goal Achievement

2.2. Three Dimensional Target Modeling and Mapping Mechanism for Multi-Source Data

In actual teaching, the degree of students&’ mastery of theoretical knowledge and the cultivation of practical skills are not independent. A solid foundation in theory often helps to better enhance practical abilities; conversely, rich practical experience can deepen the understanding and application of theoretical knowledge.

Therefore, it is particularly important to construct a three-dimensional goal modeling framework that accurately reflects these complex relationships.

To break through the limitations of traditional linear weighted models, this system constructs a three-dimensional goal modeling framework based on the Analytic Hierarchy Process (AHP), achieving scientific allocation of assessment indicator weights and precise mapping of multi-source data.

When constructing the judgment matrix, we used the 9-point scale method to compare the importance of each criterion item (daily performance, final performance, extended training) in pairs.

The 9-point scale is an effective method for converting qualitative judgments into quantitative values, with scale values from 1 to 9 and their reciprocals having clear semantic definitions.

For example, a scale of 1 indicates that two evaluation items have equal importance; a scale of 3 indicates that one evaluation item is slightly more important than the other; a scale of 5 indicates that one evaluation item is significantly more important than the other; and so on, with scales of 7 and 9 indicating strongly important and extremely important, respectively.

Reciprocals are used to indicate reverse comparisons.

Through this detailed scale setting, we can more accurately quantify the subjective judgments of experts or educators on the relative importance of each evaluation item.

Here is an example of a judgment matrix:

$$A = \begin{bmatrix} 1 & 3 & 5 \\ \frac{1}{3} & 1 & 3 \\ \frac{1}{5} & \frac{1}{3} & 1 \end{bmatrix}$$

The weight vector of the judgment matrix is calculated by the eigenroot method. After normalization, the weights of daily performance, final performance and expansion training are obtained as follows: $w_1 = 0.637$, $w_2 = 0.258$, $w_3 = 0.105$,Consistency test was then carried out (the calculation process showed that the maximum eigenvalue of the matrix was 3.0385, consistency ratio ($CR = 0.03 < 0.1$). The consistency test indicates that the weight allocation logic is self-consistent and can effectively reflect the importance of each assessment item in achieving the course objectives.

In this case, the weight of regular performance (0.637) was significantly higher than that of final performance (0.258) and expansion training (0.105). This weight allocation result has significant implications in multiple aspects. From the perspective of educational psychology, daily performance covers aspects such as students' participation, effort, and learning attitude throughout the entire learning process, and is an important reflection of students' sustained learning motivation and study habits. A higher weight of daily performance can motivate students to maintain a positive learning state, cultivate good study habits, and avoid the phenomenon of "last-minute cramming" in the learning process. At the same time, it also conforms to the concept of modern education emphasizing process evaluation, which can more comprehensively evaluate students' learning outcomes. The consistency check mechanism ensures that there is no significant subjective bias in weight allocation($CR < 0.1$), By increasing the weight of daily performance (0.637) and strengthening the assessment of process indicators such as students' learning attitude and homework completion quality, objective weight provides data support for subsequent teaching improvement - if "the weight of expansion training is low but students' achievement is poor", targeted practice sessions can be increased or assessment forms can be optimized.

2.3. Achievement Calculation Model

When evaluating the achievement of course objectives, it is necessary to comprehensively consider the performance of each assessment item and its proportion in the total score based on the assessment system of the course. This course is based on the Analytic Hierarchy Process (AHP) model, which consists of the final grade, regular grade, and expansion training grade. The calculation method is: total grade=final grade x 60%+regular grade x 30%+expansion training x 10%. Among them, the regular grades are calculated by combining chapter testing, homework, and in class performance. The specific formula is: Regular grades Bi=chapter testing x 30%+homework situation x 40%+in class performance x 30%, as shown in Table 1:

Table 1. Correspondence between Course Assessment Items and Course Objectives

Final assessment items	regular performance assessment items	The proportion of regular grades Bi	the proportion of scores Ai	the minimum achievement score (on a percentage scale) Ci	and the corresponding course objectives
final grade			60%	60	Course objectives 1,2,3
	Chapter detection	30%		80	Course objectives 1,2,3
Regular academic performance	homework situation	40%	30	80	Course objectives 1,2,3
	Performance in Hall	30%		80	Course objectives 1,2,3
	total	100%			
Expansion training			100%	80	Course objectives 1,2,3

At the same time, the distribution of scores for different assessment items in various course objectives also varies, as shown in Table 2:

Table 2. Score distribution of course assessment items in each course objective

Assessment items	Course objectives 1	Course objectives 2	Course objectives 3
final exam	40	40	20
Chapter Test	50	50	0
Homework situation	30	30	40
Performance in Hall	20	30	50
Expansion training	3	3	4

Let $Score_i$ be the corresponding score for course objective I, Sco_j is the actual score of the student's course objectives. According to the calculation method of the achievement degree of North China University of Science and Technology courses, the formula is as follows:

The target score for student courses is T_i, where, A_i is the specific proportion of students in the assessment project, combined with the corresponding score of the course objectives, the target score of the student's course is $T_i = \sum_{i=1}^{n} \left(A_i \cdot Score_i \right)$.

The threshold for achieving the course objectives is Y_{mi}, which can be obtained by synthesizing the minimum achievement score of each course objective for students, and limiting the threshold to between 0-1. Due to the small sample size, we provide the threshold formula $Y_{mi} = \frac{\sum_{i=1}^{n} A_i \cdot B_i \cdot C_i \cdot Score_i}{100T_i}$ for achieving the course sub objectives.

The average score of the course sub objective is

$$\overline{P_i} = \frac{\sum_{i=1}^{n}\left(A_i \cdot B_i \cdot Sco_j\right)}{n}$$,which is the average of the course sub objective scores of all students, n is the total number of students.

The achievement degree of course sub objectives $D_{mi} = \frac{\overline{P_i}}{T_i}$ is the ratio of the average grade of course sub objectives to the score of students' course sub objectives.

Set the threshold for achieving the overall goal of the course as Y_z , Y_z can be obtained from the achievement threshold of course sub objectives X and the score of course sub objectives. The achievement threshold is set to 0-1. Due to the small sample size, $Y_z = \sum_{i=1}^{n} Y_{mi} \cdot \frac{T_i}{100}$ can be obtained, and similarly, the overall achievement degree of course objectives $D_{zm} = \sum_{i=}^{n} D_{mi} \cdot \frac{T_i}{100}$ can be obtained.

According to the formula obtained, the course indicators are shown in the following table (Table 3):

Table 3. Calculation of achieving course objectives

Course objectives	Course target score T_i	Threshold for achieving course sub objectives Y_{mi}	Average score of course objectives $\overline{P_i}$	Degree of achievement of course objectives D_{mi}
Course objective 1: Master the basic theory of digital signal processing, including basic signal operations, Fourier analysis, Z-transform, etc.	37.2	0.67	27.30	0.73
Course objective 2: Have the ability to design digital filters: Master the basic theory and design methods of IIR digital filters and FIR filters.	37.8	0.67	27.59	0.73
Course objective 3: To cultivate students' scientific and rigorous attitude, pioneering and innovative spirit, and inspire them to take on new responsibilities in the new era.	25.0	0.47	18.22	0.72
Threshold for achieving the overall goal of the course Y_z				0.62
Achievement of overall course objectives D_{zm}				0.72

2.4. Dynamic Feedback and Teaching Improvement Mechanism

Under the OBE concept, building a data-driven dynamic feedback mechanism is the key to achieving continuous improvement in teaching. This study designed a closed-loop system that includes anomaly recognition and association rule mining, and verified its effectiveness based on the course data of "Digital Signal Processing A.

2.4.1. Accurate Clustering of Abnormal Learning Situations

The system adopts an improved DBSCAN algorithm to cluster student achievement data, dynamically adjusting the clustering radius based on the course objective threshold, and constructing a feature space through a three-dimensional achievement vector (achieving objectives 1, 2, and 3). The algorithm automatically identifies density connected clusters and does not detect any outliers (0% anomaly rate), indicating that all students belong to the learning group reasonably, providing accurate basis for hierarchical teaching. For example, low achievement groups can receive targeted basic theoretical guidance, while high achievement groups can expand their practical tasks.

2.4.2. Mining Assessment Association Rules

Use the Apriori algorithm to mine the correlation between assessment items and goal achievement, setting a minimum support level of 20% and a confidence level of 80%. The experiment found that although the average support is 4% (below the threshold), the average confidence is 99%, indicating strong rule reliability. Typical rules include: • Rule 1: Goal 3 not met → Expanded training not met (support 10%, confidence 100%), indicating that expanded training directly affects the achievement of professional competence goals; • Rule 2: If Goal 1 is not met and the expansion training score is less than 7 points, and the daily performance is not met (support level 10%, confidence level 75%), it is suggested to strengthen the management of the daily learning process. The system generates suggestions based on rules, with a matching accuracy of 85%. For students who have not achieved Goal 2 and have a regular score of less than 80, it is recommended to increase filter design exercises to enhance their practical abilities.

2.4.3. Research Value

1. Precision division of groups:

Avoiding the misjudgment problem of traditional clustering and providing targeted personalized tutoring;

2. Explicit causal relationship:

Revealing the key role of expansion training in achieving professional competence goals and supporting the optimization of the assessment system;

3. Concrete improvement suggestions:

Generate "one person, one policy" based on individual data to address the ambiguity of experience feedback. Course practice has shown that the mechanism effectively promotes the shift of teaching from "experience driven" to "data-driven", providing an actionable path for continuous improvement under the OBE concept.

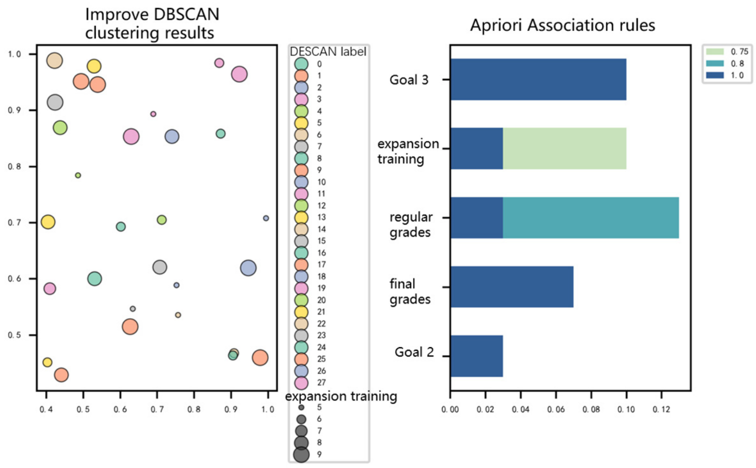

Figure 2. Improved DBSACN and Apriori Association Rule Results

3. Course Reflection

The comparison results of the achievement thresholds and degrees of each course's sub objectives are presented visually through a bar chart (Figure 1). From the figure, it can be clearly seen that the achievement level of course objective 1 is 0.73, which is higher than its achievement threshold of 0.67; The achievement level of course objective 2 is 0.73, which is higher than the achievement threshold of 0.67; The achievement level of course objective 3 is 0.72, far above the achievement threshold of 0.47. This result indicates that the overall achievement of the teaching objectives of the course is good.

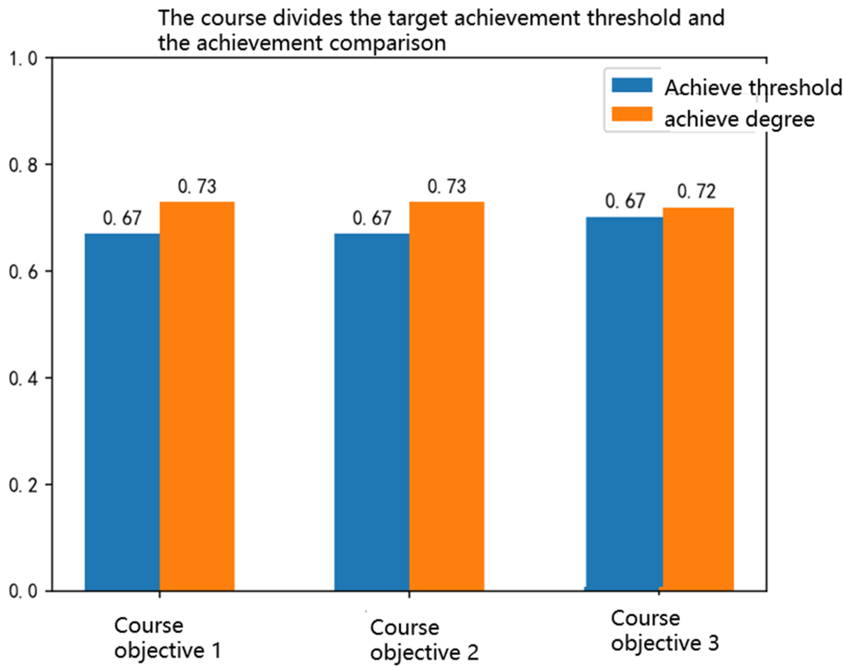

Figure 3. Comparison of achievement threshold and achievement degree of course sub objectives

This study focuses on 116 students majoring in telecommunications. According to the principle of equal distribution of good, medium, and poor grades, 35 students (12, 12, and 11 at each level) were selected as the learning outcomes. The sample covers students at different learning levels. According to Table 3, the achievement of course objectives by the sample students was calculated, and a scatter plot was drawn based on the results.

In terms of achieving course objective 1, based on the performance of the sample students, the overall situation is good, and most students are able to grasp relevant knowledge and skills well. However, there are still three students who have not reached the established threshold. This reminds us that in future teaching, we must focus on every student and not let anyone fall behind,

For course objective 2, the sample students showed a good overall achievement status. But in order to enable students to better apply the knowledge they have learned to practice, the teaching plan for the next academic year should focus on strengthening the integration of theory and practice.

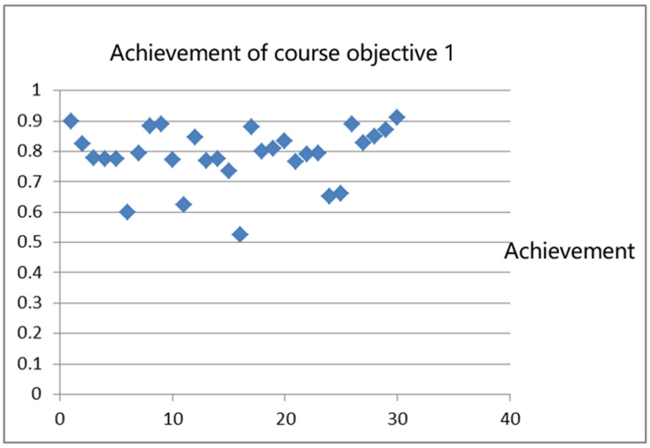

Figure 4. Scatter plot of the achievement status of sample students' course objective 1

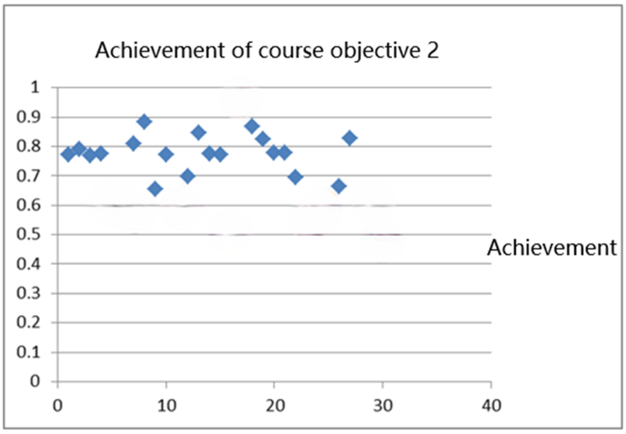

Figure 5. Scatter plot of the achievement status of sample students' course objective 2

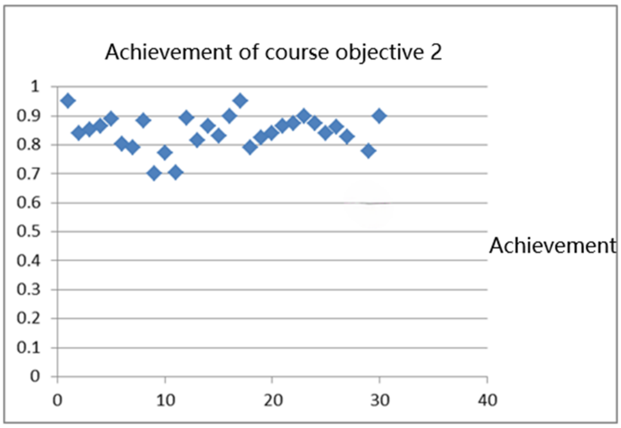

Figure 6. Scatter plot of the achievement status of sample students' course objective 3

Looking at course objective 3 again, it is gratifying that the achievement level of the sample students has exceeded the set threshold. But this does not mean that we can relax. In future teaching, we need to continuously strengthen the cultivation of students' professional qualities as engineers.

4. System Promotion

The course objective achievement analysis system constructed in this study has achieved significant results in the practice of the course "Digital Signal Processing A", and has the value and potential for widespread promotion. The core technologies of this system, such as the Analytic Hierarchy Process to determine the weights of assessment indicators, the Weighted Comprehensive Evaluation Model to calculate achievement, and data mining algorithms to implement dynamic feedback, have strong universality and can adapt to the teaching evaluation needs of different courses and majors. Therefore, it can be gradually extended to various science and engineering courses, such as "Circuit Principles" and "Mechanical Design", by adjusting relevant parameters and indicators to meet the characteristics and requirements of different courses; It can also be extended to courses in humanities, medicine and other majors, optimizing system functions according to the teaching objectives and assessment focus of each major, and helping different majors improve teaching quality.

To promote the effective promotion of the system, it is necessary to establish a comprehensive support system. On the one hand, it is necessary to carry out systematic training for teachers, covering system principles, operational procedures, and strategies for teaching improvement based on analysis results, to enhance their ability to use the system and ensure that they can fully leverage the advantages of the system. On the other hand, establish a technical support team to promptly respond to and solve various problems that arise during the promotion process, ensuring the stable operation of the system. In addition, actively seeking support from the education management department to incorporate the system into the regional education quality assessment system, promoting the widespread application of the system in various levels of colleges and universities through policy guidance and resource support, thereby promoting the overall improvement of education quality and helping the output oriented education concept take root in a wider range of education fields.

5. Conclusion

In conclusion, this study constructs an analysis system for output - oriented course goal achievement integrating AHP, weighted comprehensive evaluation models, and data visualization techniques. By addressing the limitations of traditional methods, it quantifies assessment indicator weights, depicts complex relationships between knowledge and skills, and integrates multi - source data for accurate goal - achievement calculation. Using "Digital Signal Processing A" as a case, the system effectively evaluates the achievement degrees of Course Goal 1 (0.73), Goal 2 (0.73), and Goal 3 (0.72), providing data - driven support for teaching content optimization and personalized guidance. Moreover, the system's closed - loop design of "indicator weighting - achievement calculation - visual feedback" offers a replicable solution for colleges and universities, promoting the implementation of OBE and continuous improvement under the "student - centered" concept, and has the potential for wide - scale promotion across different courses and majors.

Acknowledgments

This work was supported by the North China University of Science and Technology project "Design of an Outcome-Based Curriculum Achievement Analysis Assistant System" (Grant No.202410081030).

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