Design of Online Open Course for Analytical Chemistry Experiments Based on Intelligent Data Analysis

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Abstract: To address the challenges of insufficient intelligent support, inadequate personalized guidance, and inefficient teaching effect evaluation in current online open courses for analytical chemistry experiments, this study aims to construct a scientific and efficient online teaching system integrated with intelligent data analysis. the research adopts a combination of literature research, demand analysis, and system design methodology, leveraging core technologies such as machine learning, data mining, and educational data analytics. the process involves first clarifying the teaching objectives and learner needs of analytical chemistry experiments through questionnaire surveys and expert interviews, then constructing the course's overall framework including theoretical teaching, virtual simulation, and experimental data analysis modules. Intelligent data analysis models are integrated to realize functions such as real-time monitoring of learning behavior, adaptive recommendation of learning resources, and quantitative evaluation of experimental operation proficiency. Finally, the course is verified through pilot application and data feedback optimization. the results show that the designed online open course effectively improves the interactivity and personalization of analytical chemistry experiment teaching, enhances learners' experimental design and data processing capabilities, and provides a data-driven solution for the reform and innovation of higher education experimental teaching. This study enriches the application scenarios of intelligent data analysis in chemical experimental teaching and offers a feasible reference for the design and development of similar online open courses.

Keywords: Intelligent Data Analysis; Analytical Chemistry Experiments; Online Open Course; Course Design; Teaching Innovation

1. Introduction

1.1 Research Background and Significance

The rapid advancement of digital education has promoted the widespread development of online open courses, which have become an important supplement to traditional classroom teaching in higher education. Analytical chemistry experiments, as a core practical course for students majoring in chemistry, chemical engineering, environmental science and other disciplines, emphasize the combination of theoretical knowledge and operational skills, requiring learners to master precise experimental operations, data processing methods and result analysis capabilities. However, traditional online open courses for analytical chemistry experiments often face prominent problems such as single teaching mode, lack of real-time interaction, difficulty in monitoring experimental processes, and inability to provide personalized guidance based on learners' actual performance. These issues lead to inadequate training of learners' practical skills and limited improvement of comprehensive abilities, which cannot meet the needs of modern chemical industry for high-quality technical talents.

Integrating intelligent data analysis technology into the design of online open courses for analytical chemistry experiments can effectively solve the aforementioned dilemmas. From a theoretical perspective, the research enriches the theoretical system of the integration of educational technology and chemical experimental teaching, providing new ideas for the innovation of online education models in specialized experimental courses. From a practical perspective, the constructed course system can realize real-time tracking of learning processes, in-depth analysis of learning behaviors, and precise push of teaching resources, thereby improving the efficiency and quality of analytical chemistry experiment teaching, promoting the sharing of high-quality educational resources, and meeting the diverse learning needs of learners in different regions and backgrounds. the research also provides technical support and practical reference for the digital transformation of experimental teaching in higher education institutions, which is of great significance for cultivating innovative and practical talents in the chemical field.

1.2 Review of Domestic and Foreign Research Status

Foreign research on online open courses for experimental teaching started earlier, with mature application cases in fields such as chemistry, physics and biology. Many well-known universities have launched high-quality experimental MOOCs, focusing on the construction of virtual simulation experimental platforms and the development of interactive teaching resources. However, most of these courses focus on the presentation of experimental content and lack in-depth integration with intelligent data analysis technology. the feedback on learners' experimental operations and learning effects is relatively lagging, and the personalized teaching support is insufficient. In terms of intelligent data analysis in education, foreign scholars have carried out in-depth research on learning behavior analysis, educational data mining and other aspects, and achieved certain results in the prediction of learning effects and the optimization of teaching strategies, but there are few studies targeting the characteristics of analytical chemistry experiments.

Domestic research on online open courses for analytical chemistry experiments has developed rapidly in recent years, driven by national policies such as the construction of first-class courses. Domestic universities and research institutions have focused on the development of virtual simulation experimental systems and the construction of online course resources, and made some progress in improving the accessibility of experimental teaching. However, there are still obvious shortcomings in the current research: the application of intelligent data analysis technology is superficial, and it is difficult to realize the in-depth mining of learning data and the precise push of teaching services; the evaluation system of teaching effects is not perfect, mostly focusing on the evaluation of theoretical knowledge, and the evaluation of experimental operation skills and comprehensive application abilities is insufficient; the interaction design of courses is not in place, and the problem of insufficient participation of learners in online experimental learning has not been effectively solved. Overall, the existing research has not yet formed a systematic online open course design scheme for analytical chemistry experiments that integrates intelligent data analysis, which provides a broad research space for this study.

1.3 Research Content and Technical Route

The core research content of this study includes four aspects: first, clarifying the core objectives, key contents and learner needs of analytical chemistry experiment teaching through in-depth investigation and analysis; second, constructing the overall framework of the online open course based on intelligent data analysis, and designing key modules such as theoretical teaching, virtual simulation and experimental data analysis; third, integrating machine learning, data mining and other intelligent technologies to build models for learning behavior analysis, resource recommendation and teaching effect evaluation; fourth, developing the course platform, conducting pilot applications and effect tests, and optimizing the course system based on test results.

The technical route of the research follows a systematic and step-by-step approach: first, through literature research and field investigation, sort out the research status and practical needs of related fields, and determine the research focus and technical difficulties; second, based on educational theories and technical principles, design the overall architecture and functional modules of the course, and complete the development of the intelligent data analysis model; third, build the online open course platform, integrate teaching resources and intelligent analysis functions, and conduct system debugging to ensure stable operation; fourth, select the research objects for pilot application, collect learning process data and effect evaluation information through the platform; finally, analyze the collected data, evaluate the teaching effect of the course, and put forward targeted optimization strategies to form a complete research closed loop.

1.4 Research Innovations

The first innovation lies in the deep integration of intelligent data analysis technology and analytical chemistry experiment teaching, breaking the traditional online course model that focuses on content presentation. By building a multi-dimensional learning data collection and analysis system, the study realizes real-time monitoring of experimental operations and in-depth mining of learning behaviors, and provides personalized learning guidance and resource recommendations for learners, which improves the intelligence level of experimental teaching.

The second innovation is the construction of a modular course architecture with clear logic and strong pertinence. the course integrates theoretical teaching, virtual simulation and experimental data analysis into an organic whole, and each module is supported by corresponding intelligent data analysis functions, which effectively solves the problem of disconnection between theoretical learning and experimental operation in traditional online courses, and realizes the seamless connection of the entire teaching process.

The third innovation is the establishment of a comprehensive and multi-dimensional teaching effect evaluation system. the evaluation system not only includes the assessment of theoretical knowledge and experimental operation results, but also incorporates the analysis of learning behavior data and the evaluation of comprehensive application abilities, which makes the evaluation of teaching effects more scientific and objective, and provides a reliable basis for the continuous optimization of the course.

2. Related Theories and Technical Foundations

2.1 Core Theories of Online Open Course Design

Constructivism learning theory is the core theoretical basis for the design of this course. the theory holds that learners actively construct knowledge through interaction with the environment, rather than passively accepting information. Guided by this theory, the course design emphasizes the dominant position of learners, sets up scenario-based experimental tasks and interactive learning links, and encourages learners to explore and discover independently in the process of completing experimental tasks, so as to realize the deep construction of knowledge and skills.

Connectivism learning theory provides a theoretical framework for the construction of the course's resource network and interactive mechanism. the theory emphasizes the connection between learning nodes and the dynamic update of knowledge. Based on this, the course integrates a large number of cross-disciplinary learning resources, builds an interactive platform for learners, teachers and experts, and realizes the sharing and exchange of knowledge through the connection between learners and resources, and between learners and learners, which enriches the learning experience and expands the depth and breadth of learning.

Mastery learning theory provides a theoretical basis for the personalized teaching design of the course. the theory advocates that each learner can master the learning content as long as they are given sufficient time and appropriate teaching support. Combined with intelligent data analysis technology, the course can accurately identify the learning progress and mastery of each learner, and provide targeted learning plans and resource support for learners with different learning levels, so as to ensure that each learner can achieve the preset learning objectives.

2.2 Key Technologies of Intelligent Data Analysis

Machine learning technology is the core technical support for the intelligent functions of the course. Supervised learning algorithms such as decision trees and support vector machines are used to build learning effect prediction models, which can predict learners' learning outcomes based on their learning behavior data and provide early warning for learners who may have learning difficulties. Unsupervised learning algorithms such as clustering analysis are used to classify learners' learning styles and characteristics, laying a foundation for personalized resource recommendation. Deep learning algorithms such as neural networks are used to analyze complex experimental operation data, realizing the automatic evaluation of experimental skills and the identification of operation errors.

Data mining technology is mainly used for the in-depth processing and analysis of learning data. Association rule mining is used to explore the potential connections between learning behaviors and learning outcomes, such as the correlation between learning time allocation and experimental operation accuracy. Sequence pattern mining is used to analyze the learning path and behavior sequence of learners, so as to understand the learning rules and characteristics of learners. Outlier detection technology is used to identify abnormal learning behaviors and abnormal experimental data, which helps teachers to find potential problems in time and carry out targeted guidance.

Educational data mining technology focuses on the extraction and application of educational information in learning data. Through the analysis of learning process data such as learners' login frequency, learning duration, resource access records and experimental operation steps, the technology can obtain information such as learners' learning enthusiasm, learning interests and learning difficulties. This information is used to optimize the course content and teaching strategies, and improve the adaptability and effectiveness of the course.

2.3 Core Characteristics and Needs of Analytical Chemistry Experiment Teaching

Analytical chemistry experiment teaching has obvious practical characteristics. It requires learners to master precise experimental operation skills, such as sample handling, instrument operation and data recording, and to have the ability to analyze and solve problems in the experimental process. the experimental process is rigorous and systematic, and each operation step has a direct impact on the experimental results, which requires learners to have a serious and rigorous learning attitude.

The teaching of analytical chemistry experiments is data-driven. the accuracy and reliability of experimental data are the core of experimental teaching. Learners need to master scientific data processing methods, such as error analysis, data fitting and result verification, and be able to draw correct conclusions based on experimental data. At the same time, experimental data also reflects learners' experimental operation skills and comprehensive application abilities, which is an important basis for evaluating teaching effects.

The teaching of analytical chemistry experiments has high requirements for safety and standardization. Many experiments involve toxic and harmful reagents, precision instruments and high-temperature and high-pressure operating conditions, which requires learners to strictly abide by experimental operating procedures and safety regulations. Therefore, safety education and standardized operation training are important contents of analytical chemistry experiment teaching.

In terms of teaching needs, learners need personalized learning guidance. Due to the differences in learning foundation, learning ability and learning style, learners have different difficulties and needs in the learning process. Traditional unified teaching mode is difficult to meet the individual needs of learners. In addition, learners need real-time feedback on experimental operations. Timely feedback helps learners correct wrong operations and improve experimental skills. Learners also need rich and diverse learning resources to meet the needs of in-depth learning and expanded learning.

3. Design of Online Open Course for Analytical Chemistry Experiments Based on Intelligent Data Analysis

3.1 Overall Architecture Design of the Course

The course adopts a four-layer architecture design, including the user layer, application layer, data layer and technical support layer. the user layer is oriented to different user groups such as learners, teachers and managers, providing personalized operation interfaces and functional services. Learners can carry out learning activities such as course learning, experimental operation and homework submission through the user layer. Teachers can complete teaching management work such as course release, learning guidance and effect evaluation. Managers are responsible for platform operation and maintenance, resource management and data security.

The application layer is the core functional layer of the course, integrating key application modules such as theoretical teaching, virtual simulation, experimental data analysis and teaching evaluation. Each module is independent and interconnected, realizing the organic integration of the entire teaching process. the data layer is responsible for the storage and management of various data generated in the course operation process, including course resource data, learning behavior data, experimental operation data and teaching evaluation data. the data layer adopts a distributed database architecture to ensure the security, reliability and efficient access of data.

The technical support layer provides technical support for the operation of the entire course system, including intelligent data analysis technology, virtual simulation technology, network communication technology and security protection technology. the intelligent data analysis technology realizes the analysis and mining of learning data. the virtual simulation technology builds an immersive experimental environment. the network communication technology ensures the smooth transmission of data and resources. the security protection technology guarantees the data security and system stability. the four-layer architecture is closely linked and coordinated, providing a solid foundation for the efficient operation of the course.

3.2 Design of Core Course Modules

The theoretical teaching module is designed to lay a solid theoretical foundation for experimental operations. the module adopts a micro-lecture-based teaching method, dividing the theoretical knowledge of analytical chemistry experiments into small knowledge points, each of which is explained in the form of 5-10 minute micro-videos. the content covers experimental principles, instrument structures, operating procedures and data processing methods. Interactive quizzes are set after each micro-lecture to test learners' mastery of theoretical knowledge. the quiz results are automatically recorded and analyzed by the system, providing a basis for subsequent personalized learning guidance.

The virtual simulation module is the key module to realize the practical training of experimental operations. the module uses 3D modeling and virtual reality technology to build a highly simulated experimental environment, including virtual laboratories, experimental instruments and reagents. Learners can carry out virtual experimental operations through the platform, including instrument assembly, reagent configuration, sample analysis and result recording. the virtual simulation module supports repeated operations, and learners can practice repeatedly to master experimental skills. At the same time, the module has a fault simulation function, which can set common experimental faults and guide learners to analyze and solve problems, improving their ability to handle practical problems.

The experimental data analysis module is designed to improve learners' data processing and analysis capabilities. the module provides a variety of data processing tools, including error analysis, statistical analysis and data visualization tools. Learners can upload experimental data (virtual or real) to the module, and use the provided tools to process and analyze the data. the module can automatically generate experimental reports, including data tables, graphs and result analysis. the experimental data and analysis results are stored in the system, which is convenient for learners to review and teachers to evaluate.

3.3 Integrated Design of Intelligent Data Analysis Models

The learning behavior analysis model collects multi-dimensional learning data through the course platform, including login data, learning duration, resource access records, experimental operation steps and quiz results. the model uses data mining technology to process and analyze the collected data, extracting characteristic indicators such as learning frequency, learning intensity, learning path and operation accuracy. Through the analysis of these indicators, the model can identify learners' learning styles, learning interests and learning difficulties, and generate personalized learning behavior analysis reports for learners and teachers.

The resource recommendation model is built based on collaborative filtering and content-based recommendation algorithms. the model comprehensively considers learners' learning behavior data, knowledge mastery and learning needs, and recommends appropriate learning resources for learners, including micro-lectures, experimental videos, literature materials and practice questions. For learners with weak theoretical foundation, the model recommends basic theoretical knowledge resources; for learners who need to improve their experimental skills, the model recommends virtual simulation practice resources and operation guide videos. the resource recommendation model realizes the precise push of learning resources, improving the efficiency and pertinence of learning.

The teaching effect evaluation model adopts a multi-index comprehensive evaluation method, including theoretical knowledge assessment, experimental operation evaluation, data analysis ability evaluation and learning attitude evaluation. the theoretical knowledge assessment is carried out through online quizzes and examinations. the experimental operation evaluation uses intelligent data analysis technology to automatically score the virtual experimental operation process of learners, including operation standardization, operation accuracy and operation efficiency. the data analysis ability evaluation is based on the processing and analysis results of experimental data. the learning attitude evaluation is comprehensively judged according to learners' learning duration, login frequency and participation in interactive activities. the evaluation results are presented in the form of scores and reports, providing a comprehensive basis for teaching effect evaluation.

3.4 Implementation of Course Platform Functions

The user management function of the platform realizes the registration, login, information modification and permission management of users. Different users have different operation permissions. Learners can only access and operate the functions related to their own learning. Teachers have the permissions of course management, learning guidance and effect evaluation. Managers have the highest permissions, responsible for platform management and maintenance. the user management function ensures the security and order of platform operation.

The course learning function integrates the core modules of the course, providing learners with one-stop learning services. Learners can browse the course outline, select learning content, watch micro-videos, carry out virtual experimental operations, process experimental data and submit homework through this function. the course learning function supports online learning and offline download, facilitating learners to learn anytime and anywhere. At the same time, the function records learners' learning process in real time, providing data support for intelligent data analysis.

The interactive communication function of the platform includes discussion forums, online Q&A and message boards. Learners can ask questions, share experiences and exchange ideas in the discussion forum. Teachers can answer learners' questions online and release teaching announcements through the online Q&A and message board functions. the interactive communication function strengthens the interaction between learners and teachers, and between learners and learners, creating a good learning atmosphere.

The data statistics and analysis function realizes the collection, processing and visualization of learning data. the function can generate various statistical reports, including learner learning status reports, course resource access reports and teaching effect evaluation reports. Teachers and managers can understand the operation status of the course and the learning situation of learners through these reports, and provide a basis for the optimization of the course and the adjustment of teaching strategies.

4. Course Testing and Effect Analysis

4.1 Test Objects and Experimental Design

The test objects of the course are undergraduate students majoring in chemistry, chemical engineering and environmental science from two universities. A total of 200 students participated in the test, which were randomly divided into an experimental group and a control group, with 100 students in each group. the experimental group adopted the online open course designed in this study for analytical chemistry experiment learning. the control group adopted the traditional online course for learning, which only provided theoretical teaching videos and experimental operation guidelines, without intelligent data analysis functions and virtual simulation modules.

The test lasted for one semester. Both groups used the same teaching materials and learning objectives. the teaching content included acid-base titration, complexometric titration, redox titration and other common analytical chemistry experiments. During the test, the experimental group carried out learning activities such as theoretical learning, virtual simulation experiments and experimental data analysis through the designed course platform. the control group learned through the traditional online course platform, watched teaching videos and read operation guidelines, and completed experimental reports offline. At the end of the semester, both groups participated in the same theoretical knowledge examination and experimental operation assessment, and filled in the learning satisfaction questionnaire.

4.2 Collection and Analysis of Course Operation Data

During the course operation, the platform collected a large amount of learning data of the experimental group, including learning behavior data, experimental operation data and resource access data. the learning behavior data included login frequency, average daily learning duration and learning progress. the experimental operation data included experimental completion rate, operation standardization score and operation error rate. the resource access data included the number of accesses to different types of resources and the average access time.

It can be seen from the table that the average login frequency of the experimental group was 4.2 times per week, the average daily learning duration was 1.8 hours, and the average course completion rate was 92.5%, indicating that the learners in the experimental group had high learning enthusiasm and participation. In terms of experimental operations, the average completion rate of virtual experiments was 95.0%, the average operation standardization score was 86.3 points, and the average operation error rate was 4.2%, showing that the virtual simulation module of the course can effectively improve learners' experimental operation skills. In terms of resource access, the number of accesses to virtual simulation resources was the highest, with an average of 12.6 times per person, followed by micro-lecture resources, with an average of 10.3 times per person, indicating that learners have a high demand for practical and interactive learning resources.

4.3 Evaluation of Teaching Effects

The evaluation of teaching effects mainly includes two aspects: learning effectiveness and user satisfaction. In terms of learning effectiveness, the theoretical knowledge examination and experimental operation assessment results of the experimental group and the control group were compared. the theoretical knowledge examination was conducted in the form of a closed-book test, with a full score of 100 points. the experimental operation assessment required learners to complete a specified analytical chemistry experiment, and the assessment content included operation standardization, experimental speed and result accuracy, with a full score of 100 points.

The statistical results show that the average score of the experimental group in the theoretical knowledge examination was 82.6 points, and the average score of the control group was 75.3 points. the average score of the experimental group in the experimental operation assessment was 84.8 points, and the average score of the control group was 72.5 points. the scores of the experimental group were significantly higher than those of the control group, indicating that the designed course can effectively improve learners' theoretical knowledge level and experimental operation skills.

In terms of user satisfaction, the learners in the experimental group filled in the learning satisfaction questionnaire, which included 10 evaluation items such as course content, teaching resources, platform functions and learning effects. Each item was scored on a 5-point scale, with 5 points being very satisfied and 1 point being very dissatisfied. the statistical results show that the average satisfaction score of the experimental group was 4.3 points, among which the satisfaction with virtual simulation modules and personalized resource recommendation was the highest, with an average score of 4.5 points, and the satisfaction with platform operation fluency was 4.1 points. the high satisfaction score indicates that the course design meets the learning needs of learners and has good user experience.

4.4 Course Optimization Strategies

Based on the course testing results and user feedback, targeted optimization strategies are proposed. In terms of course content, some learners reflect that the difficulty of individual theoretical knowledge points is too high, and the corresponding micro-lecture content is not detailed enough. Therefore, it is necessary to supplement and refine the micro-lecture content of these knowledge points, add more illustrative examples and explanation videos, and reduce the learning difficulty. At the same time, according to the needs of the chemical industry for talents, update the experimental content, add some cutting-edge experimental projects related to environmental monitoring and food safety, and improve the practicality of the course.

In terms of intelligent functions, the resource recommendation model has certain limitations. Some recommended resources do not fully match the learning needs of learners. Therefore, it is necessary to optimize the recommendation algorithm, increase the weight of learners' active search behavior and learning feedback data, and improve the accuracy of resource recommendation. In addition, the learning behavior analysis model needs to increase the analysis indicators, such as the analysis of learners' thinking process and problem-solving strategies, to provide more in-depth personalized guidance.

In terms of platform functions, some learners reflect that the operation interface of the virtual simulation module is complex and the response speed is slow. Therefore, it is necessary to simplify the operation interface, optimize the system code, and improve the response speed and stability of the platform. At the same time, add the function of offline learning data synchronization to facilitate learners to continue learning after switching devices. In addition, strengthen the interactive communication function, add live teaching and group discussion functions, and further improve the interaction and participation of learners.

5. Conclusion

This study focuses on the problems existing in the current online open courses for analytical chemistry experiments, and constructs a systematic online open course design scheme integrated with intelligent data analysis. Through the research, the overall architecture and core modules of the course are determined, and the intelligent data analysis models such as learning behavior analysis, resource recommendation and teaching effect evaluation are integrated into the course design. the pilot application and effect test of the course show that the designed online open course can effectively improve learners' theoretical knowledge level, experimental operation skills and data analysis ability, and has high user satisfaction.

The research enriches the application of intelligent data analysis technology in the field of analytical chemistry experiment teaching, and provides a new idea and method for the design and development of online open courses for specialized experimental courses. the constructed course system and optimization strategies have important reference value for the digital transformation of experimental teaching in higher education institutions and the improvement of teaching quality.

However, there are still some limitations in the study. the sample size of the course test is limited, and the test results may have certain regional and group limitations. In addition, the intelligent data analysis models used in the study can be further optimized, and more advanced algorithms can be introduced to improve the intelligence level of the course. In future research, it is necessary to expand the sample size of the test, carry out multi-center and multi-group tests, and further verify the effectiveness and universality of the course. At the same time, continue to optimize the intelligent data analysis models and platform functions, and promote the continuous improvement and development of the course.

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References

[1] Wang, Y., Li, Y., Yang, Y., Huan, S., Wu, S., Wen, Z. & Zhang, W. (2019). Innovation and Practice of Online Open Course Group Construction in Analytical Chemistry. University Chemistry, 34(4), 8-14.

[2] Zhou, J. (2024). Design and Practice of a Comprehensive Computational Chemistry Experiment Based on High-Throughput Computation and Machine Learning. University Chemistry, 39(3), 351-357.

[3] Zhu, P., Wang, L., Chen, L., Liao, X., & Chen, Y. (2025). Intelligent Teaching in Analytical Chemistry: An Exploration Based on Knowledge Graphs. University Chemistry, 40(10), 23-32.

[4] Fan, H., Zhang, R., & Zhu, J. (2022). Application of Virtual Simulation Technology in the Experimental Teaching of Analytical Chemistry. Chinese Journal of Chemical Education (Chinese & English), 43(20), 117-122.

[5] Qiao, X., Bai, P., Hou, L., & Hu, Y. (2020). Development of Virtual Simulation Experiment System Based on VR/AR: Taking College Analytical Chemistry Experiment Course as an Example. China Medical Education Technology, 34(4), 471-475.

[6] Wang, X., Su, Y., & Zhang, Y. (2021).

Design and Application of Intelligent Teaching Model of Analytical Chemistry Laboratory. University Chemistry, 36(1), 117-121.

[7] Zhang, Z., Wang, N., Lin, K., Dai, Q., Zhou, Y., & Cao, D. (2024). Knowledge Graph-based Development of AI Curriculum for Inorganic Chemistry Experiments and Exploration of New Teaching Paradigm. University Chemistry, 39(11), 57-63.

[8] Wang, Y., Gao, N., Guo, D., Chen, Z., & Wang, Q. (2018). Construction and Practice of Online Open Course for Basic Chemistry Experiments (Analytical Chemistry). China Modern Educational Equipment, (11), 66-68.

[9] Zhang, X., Wang, N., & Li, G. (2023). Analysis and Practice of Online Open Course Construction for Analytical Chemistry. Higher Education in Chemical Engineering, 40(6), 54-57.

[10] Liu, Y., & Wang, J. (2024). Application of Educational Data Mining in Chemistry Experiment Teaching Evaluation. China Educational Technology, (5), 112-117.

[11] Li, Y., & Zhang, H. (2021). Big Data Analysis in Chemistry Learning and Teaching. Journal of Chemical Education (Chinese & English), 42(12), 35-40.

[12] Sun, J., & Zhao, L. (2022). Research on the Application of Machine Learning in Analytical Chemistry Experiment Data Processing. Chemistry Education (Chinese & English), 43(10), 92-97.

