

# Construction and Application of Wisdom Education Teaching Environment in Higher Education Institutions

Xiong Wang<sup>1</sup>, Xianmei Xu<sup>2,\*</sup>

<sup>1</sup>Department of Information and Laboratory Management, Sichuan University JinJiang College, Meishan, Sichuan, China

<sup>2</sup>School of Asian and African Studies, Chengdu Institute of Sichuan International Studies University, Chengdu, Sichuan, China

\*Corresponding Author.

**Abstract:** Wisdom education is one of the direction points of higher education reform, and is a new historical stage of the development of modern educational technology. With the development of information technology and the requirements of educational reform in the new era, the construction demand of higher education for wisdom education teaching is becoming more and more urgent, and the supporting teaching evaluation system has also become a hot topic of higher education research. This paper analyzes the current mainstream wisdom education teaching ways, by comparing the advantages and disadvantages analysis, integration of online teaching resources, comprehensive cost control difficulty, degree of teachers and students to accept the interview, the hardware equipment modification is proposed based on an online teaching conditions, such as construction, curriculum education resources to plan as a whole, the wisdom of teaching evaluation system of the efficiently intelligence education teaching environment. Based on this environment construction, the construction of smart education teaching platform can be completed in the form of low cost, higher satisfaction degree of teachers and students, and faster deployment time. The results show that the construction scheme and evaluation system meet the needs of higher education development, and provide a solution for the differentiated development and characteristic development of higher education.

**Key words:** Wisdom Education; Teaching Environment; Process Evaluation; Higher Education

## 1. Introduction

The development and application of networking, Internet of Things, big data integration, 5G and other technologies, have endowed teaching methods with more and more possibilities. In order to meet the needs of teaching development in the new era, wisdom education has become one of the characteristic school-running paths carefully selected by many colleges and universities. Compared with traditional teaching methods, wisdom education is more innovative and prospective in teaching means, methods, forms and channels, with higher requirements for educators<sup>[1]</sup>. Under the new situation, wisdom education is no longer a simple integration of online and offline teaching, but a reconstruction of the whole teaching process to achieve the "traceability of teachers' teaching behavior and students' learning behavior, cooperation between home and school and between teachers and students, and the high-quality development of schools", thus empowering the intelligent management and teaching of schools.

Most of the existing research focuses on the construction of smart platforms at various education levels, mainly based on hardware resources construction, and concentrating on the application of new technologies and new concepts<sup>[2]</sup>. There are also reform studies based on teaching models and methods, mainly focusing on classroom interaction, classroom extension, sentiment analysis<sup>[3]</sup>, team building<sup>[4]</sup>, teaching strategies<sup>[5]</sup>, etc. Or provide the setting and optimization of teaching evaluation system, mainly based on the combination of machine learning and artificial intelligence technology<sup>[6]</sup>. The development of wisdom education in colleges

and universities includes the above aspects, and it is necessary to construct both the wisdom education environment and the comprehensive evaluation system of wisdom education.

In this paper, combined with the wisdom of the current mainstream teaching means, by integrating the corresponding equipment and teaching resources, to effective education teaching based on build wisdom education teaching environment and the evaluation system. The intelligent teaching environment has the characteristics of low cost and high cost performance, and the evaluation system also has the characteristics of diversity, which can add, delete and allocate weights according to the actual situation, which has certain reference significance for colleges and universities. Through the actual construction and operation of the environment, the evaluation system of smart education teaching teachers and students can be explained in the form of practice, the significance of each weight is explained, and the landing and practical application of this program can be explained.

## 2. Several Existing Ways

At present, there are several mainstream teaching methods: self-directed learning on the MOOC platform, combination of learning on the MOOC platform and answering questions online, real-time teaching on live broadcast platform, experiential learning based on virtual simulation environment [7], and learning both online and offline.

Self-directed learning on the MOOC platform enables students to log in the specialized teaching platform and arrange the learning schedule on their own, without being restricted by region, time and space [8]. The platform evaluates the learning tasks by the recorded learning times and duration, and evaluates the learning effects through online tests. This kind of method requires students to have very high learning consciousness and initiative, thus is not so effective and authentic; Besides the merits mentioned above, the combination of self-learning on the MOOC platform and online Q&A can also increase the interaction between teachers and students, enabling the teachers to solve all kinds of problems in the students' learning process, while taking into account the discrepancies between students'

learning ability. However, it still fails to ensure the learning enthusiasm and initiative of the students, while making it easy for polarization to occur at the same time; The real-time teaching method based on the live broadcast platform makes it possible to ensure the initiative of students to some extent. Through live broadcast, an online "face-to-face" teaching method between the teachers and the students has been formed, enabling the teachers to monitor the learning states of the students so that they can adjust their teaching progress in time and answer the questions raised by the students. However, this method lacks an effective online teaching evaluation system in the long term; Experiential learning based on virtual simulation environment is by far the most effective learning method for experimental training courses, Particularly, it improves students' hands-on and thinking ability, and the task-driven simulation experimental platform has gradually become the mainstream of practical training courses, making up for the situation that experimental operation cannot be performed due to environment, equipment, safety and other reasons. However, this kind of teaching platform is very expensive while subjecting to professional restrictions, thus having very low popularity rate; Learning both online and offline is a special teaching method that takes into account the consistency of the learning states of students both online and offline. On the one hand, it integrates the advantages of online and offline teaching, restores the offline teaching status to the greatest extent, and on the other hand, it minimizes the impact of certain situations on overall teaching. Therefore, it remains the major learning method at the present stage [9]. The summary is shown in Table 1.

Obviously, the above mainstream teaching methods are not so much as wisdom education and teaching, but they are indeed the important premise and foundation of it. In order to achieve cooperation, process tracing and curriculum evaluation among schools, teachers and students in the teaching process, we should constantly improve the initiative, enthusiasm and creativity of teachers and students through constructing the wisdom education teaching environment, and unify wisdom teaching management, wisdom education, environment construction and

process evaluation involved in the whole process, so as to effectively improve the teaching quality of colleges and universities, creating a new characteristic school-running concept.

**Table 1. Several Existing Ways**

Serial No	Several Existing Ways	Features
1	Self-directed learning on the MOOC platform	Without being restricted by region, time and space; Autonomous learning; Low authenticity.
2	Combination of learning on the MOOC platform and answering questions online	Serial No.1; Interaction between teachers and students; Taking into account the discrepancies between students' learning ability; Lack of initiative and enthusiasm.
3	Real-time teaching on live broadcast platform	Serial No.2; "Face-to-face"; Improved initiative and enthusiasm; Lack of evaluation system.
4	Experiential learning based on virtual simulation environment	Serial No.3; Experiential learning; Improves students' hands-on and thinking ability; There are many restrictions on professionalism.
5	Learning both online and offline	It has many advantages mentioned above; Lack of evaluation system.

### 3. Intelligent Teaching Management

Due to the fact that there are so many departments, majors and classes in colleges and universities, and the teaching management of the Academic Affairs Office is complicated and difficult to quantify, together with a lack of traceability of teachers' teaching and students' learning behavior, there may be a phenomenon that teachers take teaching evaluation as the foundation while students prioritize examinations, catering to each other's pleasure. In addition, the large number of teaching buildings, wide distribution of classrooms and lack of scientific management,

have led to the uneven utilization rate of classrooms, inability to monitor the status of classrooms in real time, and unauthorized or illegal use and occupation of classrooms, resulting in waste of energy and resources in schools. To solve the above problems, most schools choose to increase personnel input to enhance class inspection or classrooms allocation. But the truth is that the effect of this method is quite limited for public resources such as classrooms are difficult to control. It is necessary to take into account the actual and emergency needs of teachers and students, and build up intelligent management to fully solve these problems.

Intelligent management in colleges and universities refers to a set of efficient and quantifiable management system formed by colleges and universities according to their own reality, characteristics and their needs of teaching and administration. It involves process development, organization, evaluation and tracing, and can be automatically controlled or switched with established strategies. With the continuous development and application of various new technologies, the quantifiable management system has been gradually evolved into a fully digitalized teaching management<sup>[10]</sup>.

### 4. Wisdom Education

Wisdom education fully embodies the "intelligence" in the teaching process, that is, the "artificial intelligence" integrated by educational behavior and process<sup>[11]</sup>.

With the wide application of information technology in colleges and universities, the educational data generated by schools are becoming more and more complicated. Through the use of big data, artificial intelligence algorithm, Internet of Things, data unification and other methods and channels, data can basically be collected, stored, transmitted, analyzed and shared almost at the same time. As the amount of information keeps increasing and the educational information types keep improving, the qualitative and quantitative analysis of diversified data in the education and teaching process has been basically realized<sup>[12]</sup>. Wisdom education should eventually pick up again its nature of serving teaching, for assisting to improve teaching quality and efficiency is the foundation of wisdom

education implementation; Information technology has endowed traditional education with "wisdom", linking online and offline channels together, and breaking through the space constraints; it has also broadened the path towards education and broken through the restrictions of communication; finally it enables the learning time to be unlimited, making free and autonomous learning the norm of education.

### 5. Environmental Construction

The teaching environment construction of wisdom education can be categorized into hardware environment construction and software environment construction. As a systematic construction process, wisdom education should not only conform to the information construction standards, architectural design standards, strong and weak current standards [13], but should also correspond to the actual teaching environment and school-running characteristics of higher education, which includes a series of problems such as equipment selection, personnel allocation, faculty quality, post-production, maintenance and system construction [14].

**Hardware environment construction:** Hardware environment construction includes the physical environment of classrooms, decoration engineering, strong and weak current, computing center, various Internet of Things equipment, etc. In terms of the physical environment of classrooms, the teaching space and desks and chairs should be equipped; the decoration project should ensure sound insulation and collection, creating a bright, simple and elegant learning environment; the requirements for strong and weak current of various equipment should be met, and spare strong and weak current mouths and cables should also be reserved; the computing center should meet the needs of real-time transmission, coding, storage and calculation in every smart classroom, respond and analyze the requests from users in time, and transmit the information to various teaching platforms; Internet of Things devices can transmit environment and state information in time, providing strong support for school management [15]; All kinds of equipment should meet the high performance requirements for online and offline teaching, such as real-time pickup acquisition matrix,

high-definition directional camera, high-definition tracking camera, real-time control and editing workstation, network and transmission equipment, intelligent central control, large screen and computer for teaching, etc [16].

**Software environment construction:** Software environment construction includes personnel input, post-production, teaching platform, utilization and maintenance of multi-platform, etc. Personnel input should meet the needs for the real-time monitoring and control of the utilization and deployment of smart classrooms, and the needs for maintenance work of post-production and release; The teaching platform should meet the needs of the individualized learning and management of teachers and students, and the control and management of various learning behaviors, which are the traceability management of teachers' teaching behaviors and students' learning behaviors; the teaching platform interacts with the multi-information platform of the campus network, and provides data support for qualitative and quantitative analysis of teaching process through synthesis, processing and analysis [17]. At the same time, the supporting system construction is also an important link in the construction of software environment. Mutual cooperation between various institutions and teaching units, the restriction of responsibility system and the code of conduct are keys to the successful implementation of wisdom education.

### 6. Process Evaluation

The quality of teaching is the essential part of the education quality of colleges and universities, and it is also the lifeline of a school. It is an important symbol for colleges and universities to achieve the scientific evaluation of teachers' teaching, students' learning and school management with the help of intelligent education and teaching environment construction.

The implementation of software and hardware environment of wisdom education and teaching creates conditions for the traceability of teachers' teaching behavior and students' learning behavior, and it also provides detailed evidence for scientific process evaluation, which can be seen mainly in two major links: the evaluation of teachers' teaching behavior, and that of students' learning behavior.

### 6.1 Evaluation of Teachers' Teaching Behavior

The evaluation of teachers' teaching behavior is mainly centered on the teaching process and teaching results, involving pre-class preparation, in-class implementation, homework management, examination management, students' evaluation of the teachers and so on. Pre-class preparation can be carried out with the help of the smart education teaching platform to finish the process scoring of courseware preparation, archiving, expert sampling, etc, which is denoted as  $x_1$ ; the whole process of teaching time, teaching process and teacher-student interaction in the class can be recorded and managed by logging in the smart teaching platform with the unique code for each teacher. It is not only convenient for students to review at any time, attend classes or participate in discussions in multiple channels and ways, but also convenient for the centralized management of the school. The score of this process is recorded as  $x_2$ . Through the recording platform, the whole class process can be transmitted, stored, edited and released in real time, and the evaluation and rating of the viewers can be completely recorded. The score of this process is denoted as  $x_3$ . Homework management makes it easy for teachers to review in time, performing automatic classification, filing and grade calculation, thus forming a perfect teaching file. The score of this process is denoted as  $x_4$ ; The examination management facilitates the management and publication of examination questions, enables simultaneous online and offline examinations, and realizes automatic management of scores. The workload of teachers in this process can be denoted as  $x_5$ . The comprehensive teaching evaluation questionnaire is used to refine the assessment indicators and truly reflect the students' evaluation of the course and teachers. The score of this process is denoted as  $x_6$ . The composition of each score can be further subdivided and quantified according to the school's situation and reality. The whole process of teacher's teaching behavior can be traced back by recording and tracking each quantitative point through the intelligent education and teaching platform. If the quantization points of each score are denoted

as  $a_i$  and the weight of each process is denoted as  $\varepsilon_i$ , then the total evaluation score  $y$  of teachers' teaching behavior can be denoted as follows.

$$x_i = \sum a_i \quad (1)$$

$$y = \sum \varepsilon_i x_i \quad (2)$$

Among them, the weight coefficient  $\varepsilon_i$  and the quantization point  $a_i$  of each score can be apportioned according to the actual situation of the school, or use the machine learning algorithm for training and fitting in the later stage to achieve the optimal evaluation<sup>[18]</sup>.

### 6.2 Evaluation of Students' Learning Behavior

The evaluation of students' learning behavior is centered on the evaluation of students' learning quality and comprehensive quality, including classroom learning, classroom interaction (process assessment), course examination and curriculum design, teacher evaluation, etc. Classroom learning is analyzed based on the frequency of students' participation in learning, such as the data of signing in, signing back, and the smart classroom camera facial image tracking, etc. The score of this process is denoted as  $x'_1$ . Classroom interaction (process assessment) is recorded through the times of interaction between the teacher and the student, answering questions, group discussion, flipping classroom, in-class practice and other records generated through the intelligent teaching platform. The score of this process is recorded as  $x'_2$ ; Course examination and course design are important indicators to inspect students' learning behavior and learning effect. They include the score data generated by online or offline examination, the course report or course design (documents, pictures, work photos or videos, etc.) submitted in the smart education teaching platform. The score of this process is denoted as  $x'_3$ . Teacher evaluation refers to the comprehensive evaluation of the student by the teacher of the subject, which reflects the comprehensive performance of the student in this course. The score of this process is denoted as  $x'_4$ . The above process constitutes the whole process traceability of student's learning behavior, and will become the process file of student's learning behavior. The composition of each score can be further subdivided and quantified according to the

school's situation and reality. If the quantization points of each score are denoted as  $a_i'$  and the weight of each process is denoted as  $\epsilon_i'$ , then the total evaluation score  $y'$  of students' learning behavior can be denoted as:

$$x_i' = \sum a_i' \quad (3)$$

$$y' = \sum \epsilon_i' x_i' \quad (4)$$

Among them, the weight coefficient  $\epsilon_i'$  and the quantization point  $a_i'$  of each score can be apportioned according to the actual situation, or use the machine learning algorithm for training and correction in the later stage to achieve the optimal evaluation.

By tracing back the whole process of teachers' teaching behavior and students' learning behavior, it not only forms a systematic teaching and learning portfolio, but also puts forward a research direction for a scientific education evaluation system, namely, achieving the optimal evaluation automatically according to the big data generated by the intelligent education and teaching platform, based on artificial intelligence. It has greatly promoted the high-quality and intelligent development of schools.

## 7. Situational Application

The application of intelligent education and teaching environment in colleges and universities should be fully reflected in two aspects: first, it is necessary to return to the essence of higher education and implement the fundamental task of education and teaching, and the intelligent teaching scene should be blended into the daily teaching activities; second, it is necessary to fully embody the wisdom in the process of education and teaching, achieve multi-channel and multi-way learning, and realize the traceability of teachers' teaching behavior and students' learning behavior.

Through the construction of software and hardware of smart education teaching environment, here are what we can achieve: teachers can upload teaching plans and materials to the cloud platform in advance, arrive at designated classrooms according to the curriculum schedule, and swipe the campus ID cards to sign in. The backstage management system will then verify the class information. After authorization, each teaching equipment will automatically start up, and the

live broadcast equipment will generate course information and stand by; when the students arrive at the designated classroom according to the schedule, they will sign in by facial recognition or mobile APP, and the teacher will receive the student attendance rate one minute before class; when class begins, the teacher just starts teaching or through manual operation, the recording and live broadcasting equipment will automatically track and switch the teacher's image during the class, and the classroom panorama will be captured, demonstrating students' learning process. Through the classroom sound source localization system, the camera can capture the special scene of the communication between the teacher and the students in time, and then automatically edit and save the video; the screen proportion of the teacher's images, PPT and blackboard writing can be automatically adjusted according to the setting ratio, and uploaded on various channels through the smart education and teaching platform for online learning; interactive activities between the teacher and the students such as in-class practice, grouping, selection and voting can be done through mobile APP, which will transmit the activity information immediately; when class is over, the audio and video generated by the class would be saved and uploaded in real time and then released according to the strategy, and the teaching and learning records generated by each information platform will also be transmitted to the management platform immediately; the teacher will press the button before he leaves the classroom, and all the teaching equipment will be shut down automatically; teaching management or other functional departments can log in to the integrated real-time monitoring platform based on their corresponding management roles, to view the teaching status and utilization status of each smart classroom and their corresponding data statistics and analysis information in real time. Big data of teaching and learning behavior will be formed by various data generated by smart classrooms from point to area, forming whole process traceability of teaching and learning behavior. To better perform the process evaluation, we can refer to the practice of Sichuan University jinjiang college (Jinjiang's). By using the machine learning algorithm fitting and adjusting the sample data over the years, in the

evaluation of teachers' teaching behavior, the score weights  $\epsilon_i$  of each process are assigned as 0.2, 0.4, 0.025, 0.1, 0.075, 0.2 respectively. In the evaluation of students' learning behavior, the score weights  $\epsilon'_i$  of each process are respectively 0.05, 0.35, 0.5 and 0.1, which can better reflect teachers' teaching behavior and students' learning behavior. At the same time, the specific quantitative indicators of  $a_i$  and  $a'_i$  of each score are shown in Tables 2 and 3.

**Table 2. Weights of Quantization Points (Teachers)**

Quantization point	Indicators	Given weight
$x_1$	$a_i$	Teaching plan and courseware preparation (0.35), relevant materials preparation (0.05), expert sampling score (0.6)
$x_2$		Start and finish classes on time (0.05), teacher-student interaction (discussion, grouping tasks, randomly choosing students)(0.7), class atmosphere (0.05), knowledge coverage (0.2)
$x_3$		Video score of recording patrol platform (0.3), expert's score and comment (0.7)
$x_4$		Assignment (0.3), assignment correction (0.65), average score or grade of the assignment (0.05)
$x_5$		Exercise arrangement (0.1), the highest score of students in the exam (0.3), and the average score of students in

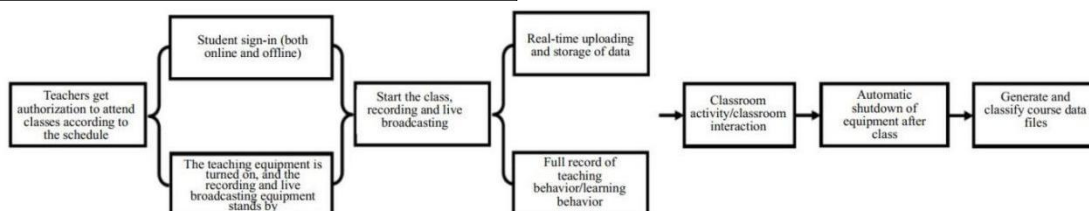
$x_6$	the exam (0.6)
	Comprehensive questionnaire of students' evaluation of teaching (0.7), teaching evaluation of teaching and research section (0.3)

**Table 3. Weights of Quantization Points (Students)**

Quantization point	Indicators	Given weight
$x'_1$	$a'_i$	Sign in (0.8), sign back (0.2)
$x'_2$		Participate in group discussion (0.15), answer questions (0.3), teacher-student interaction (0.05), practice (0.5)
$x'_3$		Examination (0.7), Curriculum Design (0.3)/Project Demonstration (0.3)
$x'_4$		Teacher evaluation (0.8), classmate evaluation (0.2)

The specific indicators of each quantitative point are not completely covered or fully participated, so they need to be selectively included in the process evaluation system according to the actual situation of each school to achieve the best adaptability. Through process evaluation, high-quality teaching courses can be popularized among the whole school, included in the optimized courses for the whole school to visit and used as an important evaluation of excellent teachers.

Through the construction of wisdom education and teaching environment, taking Jinjiang's practice as the specific use scenario, the whole work flow chart is as shown in Figure 1.



**Figure 1: Flow Chart of Wisdom Education Teaching Usage Scenario**

**8. Conclusion**

Wisdom education realizes the “one-line” teaching of colleges and universities, realizes the intelligent management of schools and the intelligent teaching of schools, and has

become an important path for high-quality, differentiated and characteristic education of colleges and universities in the new era, and also one of the powerful means to improve the core competitiveness of schools. Through the construction of the above-mentioned

intelligent education and teaching environment, the smooth transition of online and offline teaching is greatly facilitated, which not only enriches the teaching and learning channels, but also enhances the core competitiveness of colleges and universities. Through the evaluation of intelligent education and teaching process, the big data of characteristic education are formed, achieving unified storage and analysis of education and teaching data, and laying a solid foundation for intelligent education statistical decision-making. The whole system realizes the traceability of teachers' teaching behavior and students' learning behavior, which is not only necessary for colleges and universities to adapt to the development of education in the new era, but is also helpful to improve the teaching quality and promote the personnel training project of colleges and universities.

## References

- [1] Zhao Wei, Jin Xingtong. Problems and Countermeasures of Wisdom Education in Colleges and Universities. *Cooperative Economy and Technology*, 2021 (13): 74-75.
- [2] Jincheng Wang. The Essence and Composition Elements of Wisdom Education. *Science Insights*. 2021; 36 (5): 265-270.
- [3] Zhu H, Hu P, Tang X, Xia D, Huang H. NAGNet: A novel framework for real-time students' sentiment analysis in the wisdom classroom. *Concurrency Computat Pract Exper*. 2023; 35 (22): e7727.doi:10.1002/cpe.7727.
- [4] Tian Juan. Research on the Strategy of Teaching Innovation Team Construction Under Smart Education. *Education Journal*. 2023; 12 (1): 25-30.
- [5] Bi C, Zhang S, Xu S, Zou Y, Wei S. Research on Network Learning Behavior Analysis and Teaching Strategy Based on Deep Learning. *Journal of Educational Research and Policies*. 2022; 4 (4): 17-20.
- [6] Yaling Peng. Application of OBE Concept in Financial Management in the Era of Big Data. *Advances in Educational Technology and Psychology*. 2022; 6 (2): 49-55.
- [7] Xiao, X., Liu, X., & Xiao, Z. (2021). Construction and Application of Computer Virtual Simulation Teaching Platform for Medical Testing. *Journal of Physics: Conference Series*, 1915 (4), p.042074. doi: 10.1088/1742-6596/1915/4/042074
- [8] Yang Zhiyong et al. Research and Practice on the Implementation Path of Large-scale Online Teaching in Colleges and Universities. *Journal of Chongqing Radio and TV University*, 2020, 32 (04): 13-19.
- [9] Yang Ning. Research on the Application of BOPPPS Teaching Mode in the Interactive Integration of Online and Offline Teaching in Colleges and Universities During Post-epidemic Period. 2020 Conference on Education, Language and Inter-cultural Communication (ELIC 2020), 2020: 265-268.
- [10] Xu Xiang. Construct a new pattern of digital education management in colleges and universities in the era of media integration. *International Journal of New Developments in Education*, 2022, 4.0 (9): 91-95.
- [11] Seungki Shin. A Study on the Framework Design of Artificial Intelligence Thinking for Artificial Intelligence Education. *International Journal of Information and Education Technology*, 2021, 11 (9): 392-397.
- [12] Ke Bin, Lu Junjia. Data mining and utilization of college students' classroom behavior under the background of wisdom education. *Computer Knowledge and Technology*, 2020, 16 (26): 148-150.
- [13] Technical requirements for the construction of smart classrooms in colleges and universities. *China Modern Education Equipment*, 2021 (15): 160-168.
- [14] Peng Wei. Research on Typical Technical Framework, Construction and Management of Smart Classroom in Colleges and Universities. *Journal of Wuhan Shipbuilding Vocational and Technical College*, 2021, 20 (02): 28-31.
- [15] Zeeshan Khaula, Hämäläinen Timo et al. Internet of Things for Sustainable Smart Education: An Overview. *Sustainability*, 2022, 14 (7): 4293-4293.
- [16] Chen Qi, Chen Jialao. Research on Technical Framework Design and Construction of Smart Classroom. *Electronic Components and Information Technology*, 2021, 5 (12): 123-124.



[17] Tang Xiaoyan, Lou Hua. Exploration of teaching data visualization application under wisdom education. Journal of Jiangsu Economic and Trade Vocational and Technical College, 2022 (03): 56-59.

[18] Liu, Jinyang et al. Students' Course Results Prediction Based on Data Processing and Machine Learning Methods. Journal of Signal Processing Systems, 2022 (94): 1199-1211.