Practical Teaching Platform of Aircraft Maintenance Skills Based on Virtual Reality Technology

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Abstract. At present, the practical teaching effect of aircraft maintenance skills is poor, and the teaching satisfaction is low, which affects the mastery of aircraft maintenance practical skills. Therefore, this paper proposes to design a practical teaching platform for aircraft maintenance skills based on virtual reality technology. Combined with virtual reality technology, the three-dimensional display of aircraft structure is carried out, the practical teaching system of aircraft maintenance skills is optimized, and the evaluation index of practical teaching of aircraft maintenance skills is constructed. Finally, the experiment proves that the practical teaching platform of aircraft maintenance skills based on virtual reality technology has high practicability and effectiveness in the process of practical application, with a maximum fluency of 0.98 and a teaching satisfaction of more than 96%, It can better improve the teaching quality and fully meet the research requirements.

Keywords: Virtual reality · Aircraft maintenance · Teaching practice

1 Introduction

The practical teaching system of aircraft maintenance skills is an organic whole composed of various elements in practical teaching activities, including the target system, content system, management evaluation system and guarantee system of practical teaching activities. The aircraft maintenance skills practice teaching target system is a collection of the teaching objectives of the major and each specific practice link formulated by the major according to the requirements of personnel training objectives and training specifications, combined with the characteristics of the major itself. The content system refers to the specific teaching content presented by each practical teaching link through a reasonable structure configuration. The evaluation system of aircraft maintenance skills practice teaching refers to the sum of organizational management, operation management, institutional management and evaluation index system, which plays the role of information feedback and regulation in the whole system [1]. The security system is composed of teaching staff, equipment and facilities and learning environment, which are important factors affecting the effect of practical teaching. With the rapid development of aviation technology, especially the new-generation aircraft such as A380 and

W. Fu and G. Sun (Eds.): eLEOT 2022, LNICST 453, pp. 415–429, 2022.
https://doi.org/10.1007/978-3-031-21161-4_32

B787, and engines such as GP7000 and Trenti000 have been put into airline operation, the concept of aviation maintenance training is gradually changing. The modern aviation maintenance industry not only needs aviation maintenance mechanics who can perform routine inspection, adjustment, lubrication and replacement according to the requirements of maintenance work orders, but also needs advanced AMEs who can analyze the causes of failures and formulate maintenance troubleshooting plans according to aircraft failure phenomena. In the actual aviation maintenance training process, whether it is theoretical training or practical training, there is a strong demand for aircraft cockpit display or indication, operation test of each platform, and actual platform component location layout. The existing aircraft maintenance skills teaching courses can not be separated from the application of practical teaching platform. However, the teaching effect of the existing practical teaching platform is poor, and the teaching satisfaction is low, which affects the students' mastery of aircraft maintenance practical skills. Therefore, with the help of virtual reality technology, this paper builds a virtual reality aviation maintenance teaching platform, carries out aviation maintenance troubleshooting teaching research, and provides technical support for training high-level maintenance engineers who meet the maintenance requirements of modern aviation industry and the requirements of the National Excellence plan.

2 Practice Teaching Platform for Aircraft Maintenance Skills

2.1 Construction of Practical Teaching System for Aircraft Maintenance Skills

The aircraft maintenance skills competition is mainly developed according to the examination syllabus of CCAR66 "Civil Aircraft Maintenance Personnel License Management Rules" and the training syllabus of CCAR-147 "Regulations on Certification of Civil Aircraft Maintenance Training Organizations". Focusing on the 18 basic skills covered in the outline, combined with the typical job tasks of the maintenance work line, referring to the competition items and rules of domestic provincial, national and international aircraft maintenance skills competitions, fully consider the skill level and learning of the participants According to the characteristics of the aircraft, considering the facilities and equipment, select and design the aircraft maintenance skills competition items that are in line with their own. After a long period of practice, it has been proved that many basic skills covered by the license examination and training syllabus are the basic skills of aircraft maintenance. The practical teaching carried out by the school mainly includes three forms: experiment, practical training and practice, as shown in the following table:

Table 1. Categories of aircraft maintenance practice teaching

Category	Instructional objective	Content of courses	Teaching location
Experiment	Deepen the understanding of curriculum theory and knowledge points	Verify theoretical knowledge	On campus laboratory

(*continued*)

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Category	Instructional objective	Content of courses	Teaching location
Practical training	Master the basic operation skills of practical work	Individual and comprehensive vocational skill training	Both inside and outside the training base
Internship	Deepen the understanding and application of professional theoretical knowledge and cultivate professional post ability	Combination of professional knowledge and skills with actual post work	Mainly located off campus

It can be seen from Table 1 that different forms of practical teaching, teaching objectives, teaching contents and teaching locations are also different. The experimental teaching is mainly carried out in the school to master the basic knowledge; Practical teaching can be carried out both inside and outside the school, mainly to master practical operation skills; The practice teaching is generally outside the school, paying attention to post training and combining professional knowledge and skills with the actual post work.

In the final analysis, various forms of aircraft maintenance skill competitions held at home and abroad mainly focus on the basic skills of aircraft maintenance - the competition of 18 basic skills. Therefore, civil aviation colleges and universities should be built into license test sites and training sites with CCAR66 and CCAR-147, and carry out practical skill teaching with the high standards of license test sites and training sites, so as to make greater contributions to the cultivation of high-quality skilled talents for civil aviation. At present, the domestic license examination sites are limited, and most of the training and examination sites with basic skills are major airlines and maintenance companies. Therefore, civil aviation colleges and universities and ordinary

Table 2. Development of basic skills for aircraft maintenance

Serial number	Project	Sub item
A	Maintenance manual and maintenance documents	AMM query, IPC query, WDM query
B	Line standard construction	Binding and installation of conductor bundle, repair of conductor and cable, construction of shielding ground wire, crimping and installation of lug
C	Simple electronic circuit making	Manufacture of sound light control circuit, simple alarm, amplification circuit and electronic clock
D	Aviation	Disassembly and assembly of hydro mechanical components, fuel pump components and static converter

colleges offering aircraft maintenance major still have a long way to go in cultivating high-quality skilled talents in aircraft maintenance. Except item 1, basic skills of aircraft maintenance are not suitable for hands-on skills competition. Other basic skills can be divided into component projects, for example, as follows.

The aircraft practical teaching system is an organic closed-loop platform. As shown in the figure, the constituent elements coordinate with each other in operation to jointly achieve the training goal of the practical teaching system. Based on this, the closed-loop architecture of aircraft maintenance practice teaching is optimized as follows (Fig. 1):

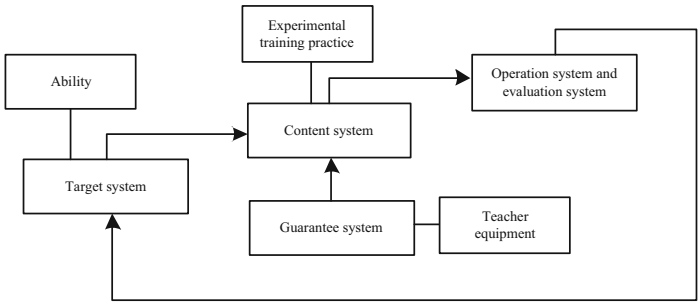

Fig. 1. The closed-loop architecture of aircraft maintenance practice teaching

Through the analysis of the demand for maintenance talents, this major is positioned to serve HNA and face civil aviation. Graduates are mainly employed in target positions such as route maintenance mechanic, scheduled maintenance mechanic and so on. Analyze the job groups and professional abilities of graduates, and determine the professional ability, method ability and social ability required by students. Based on this, the basic skill training ability score of aircraft maintenance practice is optimized, as shown in Table 2.

Basic skill training is mainly to cultivate the basic skills required for aircraft maintenance, such as correct use of tools and measuring tools, basic fitter skills, insurance, basic line construction skills, basic electronic welding skills, etc.; Operation skills and comprehensive skills are mainly to cultivate the ability to complete the inspection, testing, disassembly and other maintenance of aircraft components and platforms, which are implemented in the practice courses of various professional core courses. The courses are designed according to the integration of theory and practice, and the difference between theory and practice is blurred; Maintenance skill training is to cultivate students' ability to complete the actual maintenance of aircraft platform and their ability to work directly. It is completed through post practice in the form of "apprenticeship" (Table 3).

2.2 Optimization of Practical Teaching Steps for Aircraft Maintenance

Aircraft maintenance practice teaching and training courses are accelerating the realization of full VR coverage, which provides conditions for students to log in to virtual reality anytime, anywhere and conduct online learning. As a national demonstration center, the

Table 3. Analysis of basic skills training ability in aircraft maintenance practice

Position/job description	Comprehensive professional ability		
	Vocational ability	Method capability	Social ability
Route maintenance mechanic, complete the signing of mechanical element items in routine work cards before, after and after flight	Sign and support a series of documents such as laws and regulations and industry standards related to aircraft maintenance	Basic knowledge of aircraft maintenance, knowledge of human factors and accident prevention, ability to consult documents and solve maintenance problems	The consciousness of observing discipline and law and the quality of honesty and trustworthiness; Good communication skills, strong awareness of laws and regulations and strong awareness of safety responsibility
Regular inspection and maintenance mechanic, complete the preparation and signing of aircraft regular inspection routine work card	Basic skills such as regulations and industry standards related to aircraft maintenance		
Job descriptions of structural maintenance mechanic, customer inspection maintenance mechanic and accessory maintenance mechanic are omitted			

engineering center has built various Boeing project laboratories, and teachers have developed a large number of self-made equipment has built a good physical classroom teaching environment [2]. Therefore, according to the "learner-centered" educational concept, a virtual reality teaching mode combining "online and offline" is proposed. Skills and knowledge are interrelated, according to the characteristics of aviation maintenance, to master the skills must first have a certain theoretical knowledge [3]. Theoretical knowledge can be put online, and the learning tasks are carefully designed and completed by the students online, while the hands-on operation is placed in the offline practice room, which indirectly prolongs the hands-on operation time and improves the efficiency. The teaching implementation process is shown in the figure. First, the authentication function module of virtual reality is used to restrict the learners, and then the selected candidates are given three stages of blended teaching before class, during class and after class, and the learning effect is evaluated (Fig. 2).

Virtual 3D scene applications can generally be divided into two categories [4]. One is the application platform for product design verification and analysis, which is mainly used for the verification and analysis of product design and maintainability. The other is the application platform for the training of users or maintenance personnel, which is mainly used for the training of equipment operation or maintenance personnel. There are similarities between the two, but there are also many differences in interactivity, model accuracy and scene authenticity [5]. The characteristics and differences between the two are shown in Table 4.

According to the principle of "taking the needs of competent professional posts (groups) as the goal, taking the cultivation of comprehensive professional ability as the

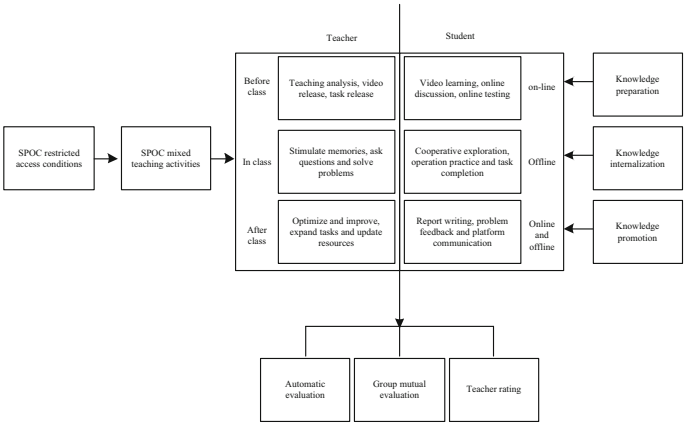

Fig. 2. Hybrid teaching evaluation system based on virtual reality

Table 4. Features and differences of virtual 3D scene teaching applications

Characteristic	Design verification application	Training application
System pertinence	Design defects and maintainability	Skill training
Scene reality	Lower	Higher
Model accuracy	Very high	Commonly

main line and meeting the requirements of employers as the quality standard", the aircraft maintenance curriculum system of our college generally adopts the curriculum development method of learning field based on "combination of work and study". Follow the logical sequence of "determining the job group faced by the specialty - Analysis of typical work tasks - description of action field - induction and classification of professional ability - induction of learning field - development of learning situation", reconstruct the aircraft maintenance practice teaching course system, as shown in Fig. 3.

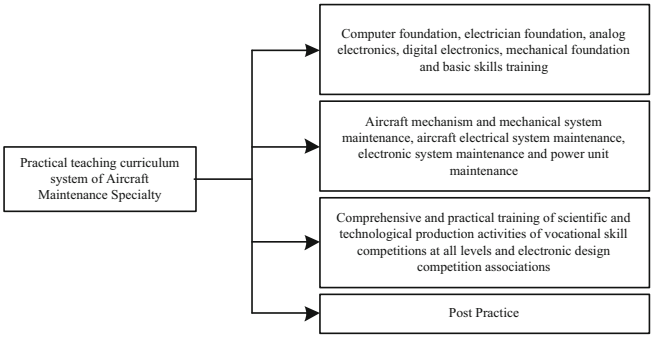

Fig. 3. Reconstruction of aircraft maintenance practice teaching curriculum system

Aircraft maintenance reforms the traditional teaching method according to the learning link of "functional platform knowledge learning (platform working principle explanation) - familiarity with the position and function (cognition) of aircraft and various platform components - typical maintenance work tasks (practice)", and the teaching organization is fully implemented Project-based teaching. If X is the number and quality of people, Y is the number and quality of weapons, and L is the combat power, the combat power formula can be expressed as:

$$L = (aX + Yb) \otimes Zc - 1 \tag{1}$$

In the formula, a, b, and c are variable parameters. X reflects the role of aircraft components, Y reflects the role of weapons and equipment, and Z reflects the combined role of factors such as the environment. This formula has a wider scope of application and can be used to reflect different manifestations in different periods. In the process of teaching design, use information technology to give full play to the role of teaching software [6], carry out the construction of an open teaching platform, and arrange teaching around a complete task or situational design, so that students become the role of the task, and the teaching process becomes the task for students to complete [7]. process, so that each student can learn and develop actively and lively, and embark on the road of becoming a talent. The teaching management process of aircraft maintenance is shown in Fig. 4.

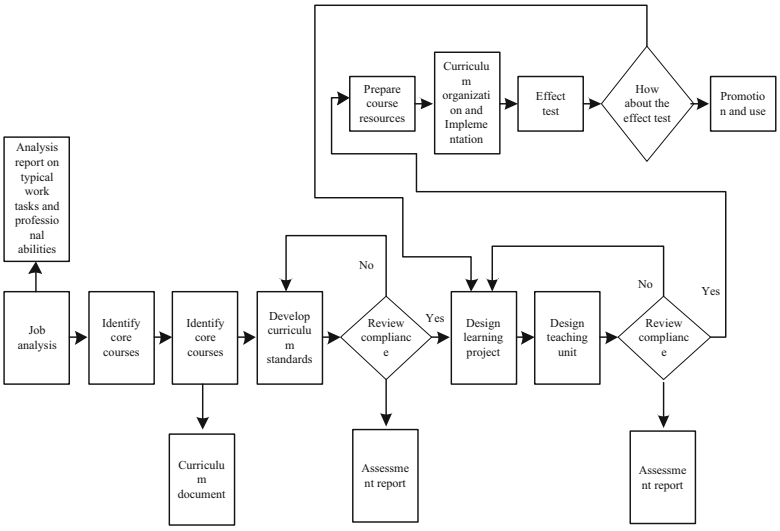

Fig. 4 Aircraft maintenance teaching management process

Take the typical work tasks of the main civil aviation models B737-800 and A320 as the carrier, take the completion of work tasks as the goal, take action orientation as the curriculum implementation principle, and develop the learning situation according to the aircraft maintenance work order to achieve "the consistency between the learning

field and the work field, the learning process and the work process, and the learning task and the work task." In order to establish the evaluation model, it is generally necessary to determine the evaluation index first [8]. Selection and significance of evaluation indicators taking pre flight maintenance training as an example, the training platform selects the first-class indicators of work integrity, use of tools and equipment and completion time for evaluation [9]. Work integrity represents work completion and overall quality, such as whether all safety pins and plugs are removed and whether all parts are in normal position during aircraft pre flight maintenance; tool use includes correct selection, validity inspection and basic use methods of tools; completion time reflects work familiarity, operation efficiency and rationality of path planning. According to the above analysis, the comprehensive evaluation hierarchy model is established as shown in Fig. 5.

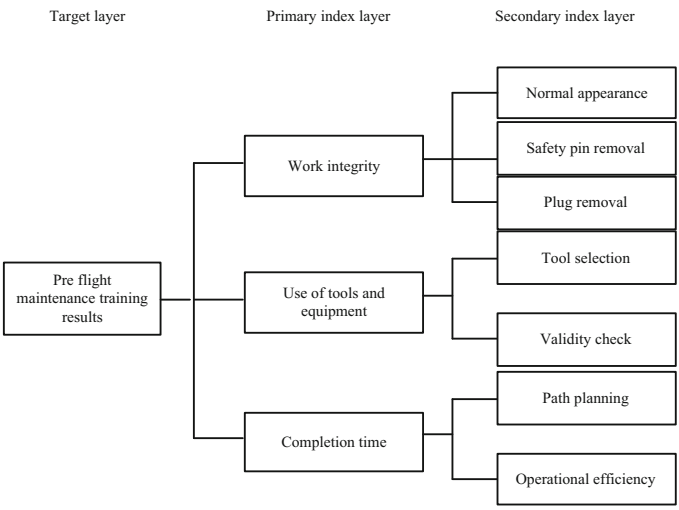

Fig. 5. Teaching evaluation hierarchy model

The hierarchical evaluation structure model of teaching evaluation has high dependence and requirements on experts. The judgment matrix method can solve the problems that require high evaluation experts, and has a certain accuracy. It combines the ancient forest method and the pair-by-pair comparison method. The respective advantages simultaneously avoid their respective disadvantages.

2.3 The Practical Teaching System of Aircraft Virtual Maintenance

As the application of virtual reality technology in the field of maintenance training, aircraft virtual maintenance training platform combines the methods and technologies of virtual reality technology, computer programming technology, human–computer interaction technology, three-dimensional driving technology, aviation maintenance engineering, education and teaching and so on [10]. There are not only independent parts but also internally related parts among various technical fields. In the process of research and

development, the tasks of each stage need to be planned as a whole. The basic research and development process of this paper is shown in Fig. 6.

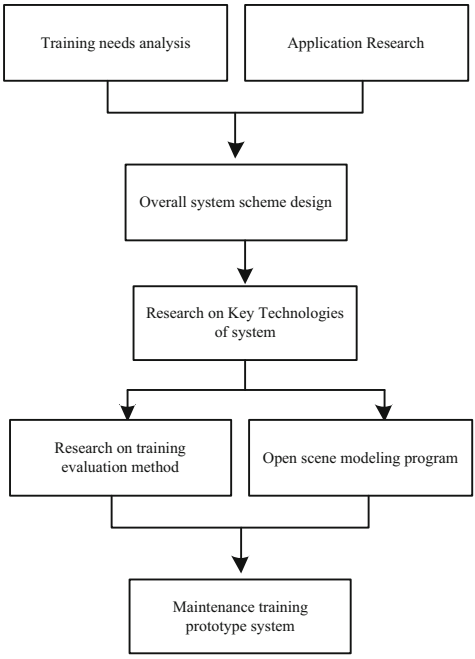

Fig. 6. Research and development process of virtual maintenance training platform

The hybrid teaching model based on the virtual reality comprehensive platform aims to improve the teachers' ability to apply modern educational technology and the students' independent learning ability under the information technology environment. Objective evaluation of teachers' teaching situation on the virtual reality platform, and effective and timely feedback will help teachers to improve teaching strategies and improve teaching effects. Taking the engine principle course as an example, teachers can see the number of times students log in to the teaching platform to learn on the virtual reality platform, update teaching resources, interact with students to answer questions, and review students' online test assignments on the virtual reality platform. By publishing course notices, students can enter the virtual reality platform task module to learn in time. In order to objectively evaluate the process of blended teaching, the standard of blended teaching evaluation and the score of each item are designed. As shown in Table 5.

The virtual reality aviation maintenance practice teaching equipment uses the maintenance training resources of the world's largest aviation maintenance training data network AVSOFT, the Boeing network platform authorized by the Civil Aviation University of China, the Airbus l World Airbus online platform, the French Safran Group MCDU software and hardware and A3203DV ewer and other software, combined with touch display technology, equipped with Window8 operating platform for secondary development of four-screen display interactive aviation maintenance practice training

Table 5. Details of evaluation index parameters of mixed teaching

Evaluating indicator	Describe	Weight (%)
Teaching resources	Whether teachers' online teaching resources are rich, relevant to teachers and meet students' needs	30
Student interaction	Whether the interaction between teachers and students on the network teaching platform is timely and accurate	15
Student participation	The number of times students complete their homework online and the effective number of times they download teaching resources	30
Instructional design	Take students as the center, organically integrate knowledge, ability and quality, and improve students' participation	25

equipment. Provide multi-level maintenance training according to the knowledge level and stage of the trainees. The task level and target diagram of the training platform are shown in the Fig. 7.

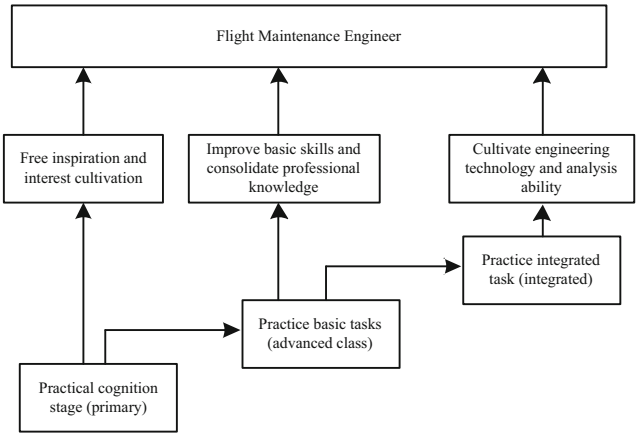

Fig. 7. Aircraft maintenance training task hierarchy and objectives

As can be seen from Fig. 7, practice is an important part of the practical teaching link of technical undergraduate education. The purpose is to enable students to have a deeper understanding of the society, contact the front line of enterprise production, understand the dynamics and needs of industry and enterprise development, and improve students' practical ability through professional related social investigation, industry investigation, interview and consulting services according to the requirements of professional talent training program Professional skills and social practice ability.

The computer processing center is connected to the Boeing network platform through the network interface to obtain real-time and effective aviation technical reference materials and digital maintenance management software: Airbus World Airbus online platform and aircraft maintenance analysis software AIRMAN: Av soft com WBT AlD EMO and other aviation maintenance training materials. Connect Safran MCDU hardware and software devices through the USB interface. Connect the multi-screen display processing components through HDMI to output the interactive cockpit touch display, Wed3D component display, ECAM display and platform working principle diagram and AMM, FIM and other technical information display, as shown in Fig. 8.

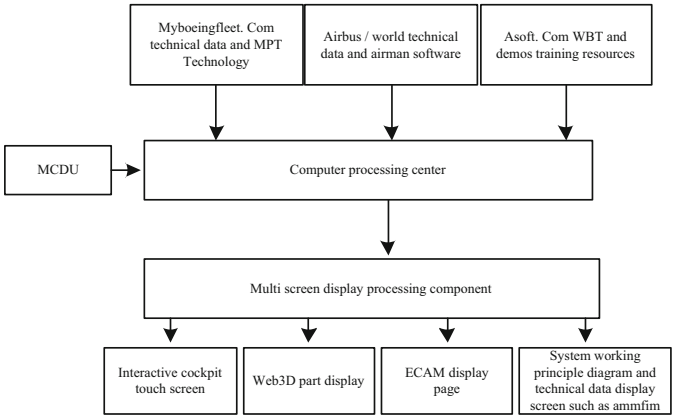

Fig. 8. Display structure of aircraft maintenance course based on virtual reality

It can be seen from Fig. 8 that qualified maintenance and troubleshooting engineers must understand the functions, positions and interconnections of the main components of the platform; Understand the fault indicator and verify the aircraft fault indication; Use fault diagnosis strategy to analyze faults; Use platform self-test equipment or other equipment; Read and analyze the self inspection results; Statistical analysis summarizes which parts of the platform are prone to failure; Use the maintenance technical data to perform fault isolation procedures and maintenance tasks. Therefore, the difficulty of training maintenance troubleshooting engineers is to teach students to reasonably use fault diagnosis strategies, equipment and methods for troubleshooting. Taking the virtual reality aviation maintenance practice teaching equipment as the carrier, this section discusses how to design the troubleshooting teaching process from the aspects of fault case selection principle, fault indication, troubleshooting process and strategy.

3 Analysis of Experimental Results

In order to verify the effectiveness of the aircraft maintenance skills practical teaching platform based on virtual reality technology designed in this paper, the platform functions are tested after development, and the test results are shown in Table 6.

Table 6. Platform functional test results

Serial number	Test content	Test result
A	Student login	Normal
B	Student registration	Normal
C	Teacher registration	Normal
D	Teaching process management	Normal
E	Teaching document management	Normal
F	Personnel management	Normal
G	Asset and fund management	Normal
H	Administrator login	Normal
I	Administrator registration	Normal

It can be seen from Table 6 that the practical teaching platform designed in this paper runs stably and has good security, which meets the initial needs of the platform and can solve the difficulties in practical teaching to a certain extent. In order to further verify the practical application performance of the platform designed in this paper, the functionality of the platform is tested. Table 7 shows the platform function test results, and Table 8 shows the platform configuration test results.

Table 7. Platform function test report

Functional testing				
Serial number	Test content	Test result	Test comments	Remarks
A	Interface test	Basically meet the requirements	Individual interfaces need to be modified in color matching	There are too many interfaces and only one general evaluation result can be given
B	Functional testing	Generally, it meets the initial design requirements	Some modules need to be improved and optimized	——

It can be seen from the test results in Table 7 and Table 8 that the practical teaching platform designed in this paper still has the problems of too many interfaces and slow data reading. However, these problems can be easily solved. The platform data interface model can be unified through the interface conversion tool to reduce the interface complexity; The data of nearly two years is transferred to the historical database. Dividing the query data by time can increase the response speed of the platform. For the student module and teacher module, if the interface development of the integration platform is

Table 8. Platform configuration test report

Serial number	Test content	Test result	Test comments
A	Configuration test	Satisfied	—
B	Time response test	After increasing the database records to 100,000, the query speed of users is relatively slow	It is recommended to transfer the data of two years to the historical database
C	Pressure test	There are two special service platforms for practical teaching in higher vocational colleges, with CPU speed of 10 G, memory of 8G and hard disk of 500 g	—
D	Capacity test	At the same time, 500 users are concurrent, and the capacity test performance is good	—
E	Safety test	Quite safe	—
F	Recovery test	Good recovery	—
G	Backup test	The backup performance of system execution code and database is good	—

not perfect, the interface design of the stored procedure is incomplete, or the interface cannot be integrated, the integration test will be affected and the integration test will be stopped. In order to ensure the rationality of the online aircraft maintenance practice teaching platform designed in this paper, its use process is simulated to test the running fluency of the platform, and the comparative test method is adopted. The parameters and transmission values of the compressed transmission data are set to ensure the fairness and accuracy of the detection results. Select the traditional practice teaching platform as the comparison platform, and conduct 6 random tests to compare the smoothness of the platform. The higher the smoothness, the better the platform operation effect and the better the user experience. Table 9 shows the comparison results of the running fluency of the two platforms.

It can be seen from Table 9 that in the six random tests, the fluency of the traditional practice teaching platform basically remained between 0.670.75, with a maximum of 0.75; The fluency of the practical teaching platform designed in this paper remains above 0.93 and the maximum is 0.98, which shows that the time teaching platform designed in this paper has good fluency and user experience in actual operation.

Table 9. Platform running fluency comparison test

Number of tests	Traditional method	The method of this paper
a	0.68	0.98
b	0.67	0.93
c	0.69	0.98
d	0.73	0.95
e	0.68	0.97
f	0.75	0.93

The teaching quality of the platform was further verified by experiments for comparative analysis, and the satisfaction of teachers and students on the use of the teaching platform under the traditional teaching mode and the teaching mode of this paper was recorded and recorded. The specific test results are shown in Fig. 9.

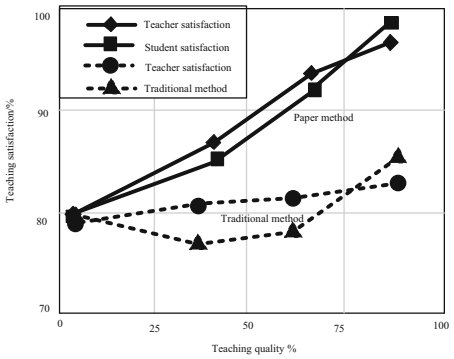

Fig. 9. Comparison of experimental test results

It can be seen from Fig. 9 that the teaching quality of the two platforms is in direct proportion to the teaching satisfaction. Under the condition that the teaching quality of the two platforms is basically the same, the teaching satisfaction of the traditional practical teaching platform is basically about 85%, while the teaching satisfaction of the practical teaching platform designed in this paper is basically more than 96%, which shows that the platform designed in this paper can not only improve the teaching quality, but also increase the teaching satisfaction, and has a good practical teaching effect. It can maintain a good running state in the network environment and fully meet the current research requirements.

4 Conclusion

Aiming at the problem that the practical teaching effect of aircraft maintenance skills is not good at present, this paper proposes a design method of aircraft maintenance skills practical teaching platform based on virtual reality technology. The construction of aircraft maintenance teaching mode based on virtual reality has reorganized the teaching process and promoted the change of teaching concept. Teachers have changed from classroom instructors to course organizers, realized the organic combination of online theoretical learning and classroom hands-on operation, and effectively solved some problems existing in aircraft electronic maintenance teaching. Although the application of virtual reality in curriculum reform is still in the process of continuous exploration, it plays a great role in improving students' autonomous learning ability, has a very positive significance in improving the quality of practical teaching, and provides a reference for the informatization of aircraft maintenance practical teaching.

Fund Project. Research topic of Beijing Polytechnic: Practical Teaching Platform of Aircraft Maintenance Skills Based on Virtual Reality Technology.

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