Development and Application of Online Training Teaching Platform for Land-Based Ship Engine Room

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Abstract: In alignment with the Chinese directive to enhance undergraduate education reform and talent cultivation quality, an online training platform has been developed to supplement on-site instruction, leveraging advanced technologies like panoramic interaction. This innovation is grounded in the resources of our land-based engine room laboratory. The platform's performance was stress-tested using Apache Jmeter, yielding favorable results that confirm its stable and smooth operation within specified parameters. Its implementation has yielded noticeable improvements in learners' practical training outcomes, offering tangible evidence of its efficacy. The emergence of this land-based engine room online training platform marks a pivotal milestone, bridging the gap in the application of panoramic interactive technology within the marine engineering education sector and the establishment of simulation-based operational teaching platforms in China.

Keywords: Land-Based Engine Room; Simulation Teaching; Online Platform; Panoramic Interaction

1. Introduction

In order to implement the spirit of documents such as the Ministry of Education's Opinions on Accelerating the Construction of High-level Undergraduate Education and Comprehensively Improving Talent Training Ability, as well as the Opinions on Deepening the Reform of Undergraduate Education and Comprehensively Improving the Quality of Talent Training, in July 2021, the Department of Higher Education of the Ministry of Education of China issued a notice regarding pilot work for the construction of Virtual Teaching and Research Offices[1-4].

The notice emphasizes the full utilization of information technology to explore innovative ideas, methodologies, and models for higher education in the "intelligent plus" era, with a shared goal of building high-quality online teaching resources[5,6].

In February 2022, the Ministry of Education of China announced a catalog of the first batch of 439 national virtual teaching and research office construction projects. Since then, numerous colleges and universities have been actively engaged in relevant work, initiating the construction of diverse new teaching resources, including online practical training teaching platforms[7-9].

For instance, scholars at Guilin University of Technology have developed a virtual simulation laboratory for drone photogrammetry utilizing 3D reality. Meanwhile, at Henan Broadcasting University, educators have designed and constructed online education course resources based on cloud platforms. Additionally, the University of Electronic Science and Technology of China has created a platform for infrastructure resource sharing systems (Platform as a Service - PaaS) within a virtual cloud computing environment. However, in the realm of Marine engineering education, there is a scarcity of reports discussing the establishment and application of thin client practical training teaching simulation operation cloud platforms that are grounded in world-class land-based ship engine room laboratories and cutting-edge information technologies such as virtual reality (VR), panoramic interaction, and cloud services.

The Land-based Engine Room Laboratory of Dalian Maritime University was established and commissioned in 2013, spanning an area of 5,600 square meters. This laboratory is equipped with the newest generation of ocean-going merchant vessel electromechanical equipment and adheres strictly to the AUTO-0 unmanned engine room standard prescribed by China Classification Society. It stands as a preeminent, comprehensive experimental platform for Marine engine rooms, both domestically and internationally, and currently shoulders the pedagogical responsibilities for mandatory courses in Marine engineering comprehensive practical training (1 credit) and engine room resource management (1 credit) for undergraduates specializing in Marine engineering management, alongside a plethora of scientific research undertakings[10].

The system in the laboratory is very complex, the equipment is very expensive, and the energy consumption and maintenance costs such as fuel and electricity are hundreds of thousands of yuan per year. In addition, undergraduates lack practical ship operation experience, which leads to a very high safety risk in on-site teaching. In the period of the COVID-19 pandemic, we implemented a live teaching mode, but this teaching mode is not conducive to improving learners' practical ability.

In an effort to echo the Ministry of Education's directives, address numerous shortcomings in land-based engine room practical training, and bridge related gaps in the Chinese educational landscape, the project team has devised and implemented an online simulation practical training platform for the land-based engine room. This platform is distinguished by its ability to transcend time and space constraints, offering efficiency and convenience as a complement to on-site instruction. These endeavors constitute a pivotal component of our university's national virtual teaching and research office application project, as well as research initiatives undertaken by the Chinese Higher Education Association and other affiliated projects.

2. Overall Design of Teaching Platform

The teaching platform includes functional modules such as virtual classroom, simulation operation and VR operation, and the process and overall framework are shown in Figure 1.

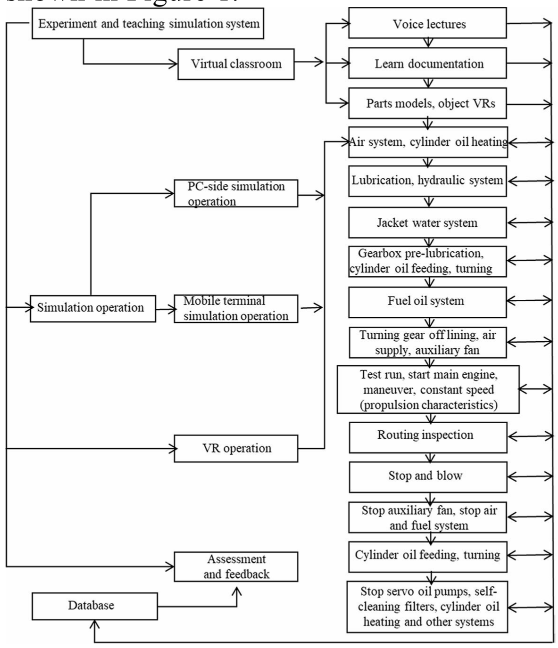

Figure 1. Framework of Online Practice Teaching Platform

Accessing the immersive virtual classroom module, learners can engage with a range of interactive controls during their navigational exploration, facilitating practical mastery through the utilization of audio recordings, digital educational materials, 3D representations of components and apparatus, or object-based VRs. By incorporating simulated and VR-based operations, learners gain access to sub-modules and subsystems such as air, cylinder oil, lubrication, hydraulics, jacket water systems, gearboxes, and fuel oil systems. This occurs within online simulations encompassing standby mode, startup, maneuvering, oil changes, constant speed inspections, and engine shutdown, all executed via intuitive human-computer interactions. Each action and resulting system state is logged within the database, accessible to instructors through the assessment and feedback feature. Data insights derived from these interactions inform refinements to teaching methodologies, enhancements to course content, and advancements in the learning platform. Consequently, this iterative process completes the continuous cycle of constructing and refining the online simulation-based practical training environment.

3. Construction of Teaching Platform

3.1 System Deployment

The online training and teaching platform of the land-based engine room is based on the Browser-Server (B/S) architecture, which can be deployed on the cloud server or Intranet server, as shown in Figure 2.

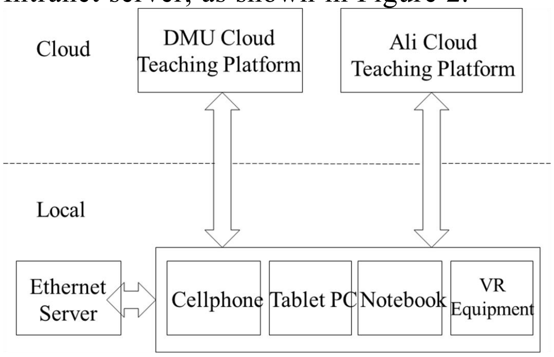

Figure 2. System architecture of online practice teaching platform

Currently, the platform is hosted on the cloud server of Dalian Maritime University and the Elastic Compute Service (ECS) server of Alibaba Cloud, enabling learners to seamlessly access it via various devices equipped with web browsers. Alternatively, we can designate a computer within the local LAN as the server for system deployment, allowing learners to access it through other devices connected to the Intranet.

The platform's functionality is browser-dependent, eliminating the need for additional app installations, software downloads, or plug-in integrations. Testing has confirmed stable access and operational functionality on browsers such as 360, QQ, Cheetah, UC, Firefox, and others. The range of compatible devices extends to computers, mobile phones, tablets, VR headsets, and more.

3.2 Key Technology

Virtual simulation is a comprehensive integration technology, which uses one system to imitate another real system. A new generation information technology is used in the development of the land-based engine room online practical training teaching platform, with the help of mainstream development tools such as 3D Max, Dreamweaver and MySQL. Use HTML, JavaScript, PHP, etc. as auxiliary development languages. The platform architecture is based on HTML5 design and supports mobile terminals. The 3D scenes are made up of high-definition panoramics of the land-based engine-room laboratory, enabling a binocular split-screen display. Human-computer interactions in these scenes are implemented by JavaScript programs that read the XML parameters and run them in HTML pages.

In the development process, different system states correspond to different variables, and the variable values are logical judgment conditions. The operations of human-computer interactions are realized by triggering events combined with a variety of timer methods.

The database of the platform is MySQL, and the interface language is PHP embedded in HTML. Use Dreamweaver as the script editing tool and Photoshop, PTGui, and Autopano Giga as the graphics processing tools. Some of the objects in the scene are modeled using 3D Max and the model files are invoked using the ThreeJS engine. The underlying technology is WebGL.

The platform can be deployed in a private or public cloud or locally. If the platform is deployed in the cloud, the operation of the system depends on the computing power (cloud computing) and bandwidth support provided by the cloud service provider.

3.3 Functions and Modules

3.3.1 Virtual classroom

Virtual classroom module realizes teaching and learning functions through different controls in different scenes. Activate the teaching control to call and play the audio file, activate the handout control to call the relevant documents of the digital teaching materials. Some devices and components in the scene are also activated controls, which can be activated to call the object VRs, or 3D model for learning the structure, principle and working process of the electromechanical equipment.

Learners can activate various controls and complete various learning tasks while roaming and walking in the scene. As shown in Figure 3.

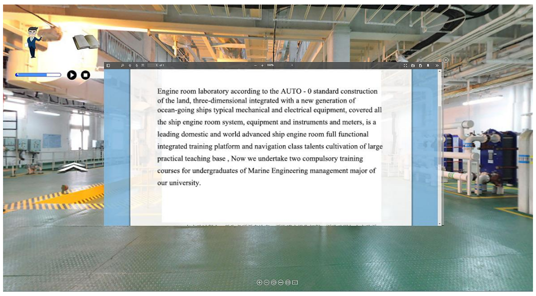

Figure 3. Virtual Classroom Scene

3.3.2 Simulation operations

Simulation exercises are structured into multiple tiers, with entry points for each tier aligned with the operational workflow of standby mode, maneuvering, and engine shutdown. These tier-specific icons, along with status-varying test buttons organized based on operational relevance, are suspended within the platform's catalog scene, forming a navigational roadmap as illustrated in Figure 4.

The icons and buttons serve as gateways to individual action submodules. Once a learner completes the assigned tasks within a tier and returns to the navigational interface, the icon representing the completed tier will indicate completion status, triggering automatic activation of the subsequent tier's icon.

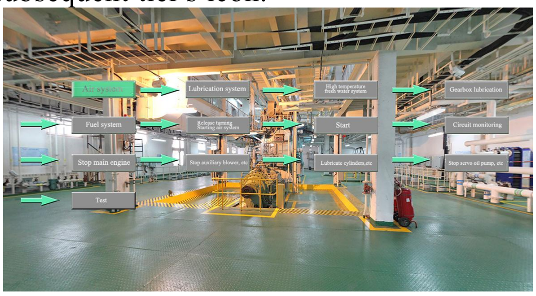

Figure 4. Operation Scenarios of Directories

Figure 5 is one of the scenarios for starting an air compressor. In the scene, learners can arbitrarily switch the Angle of view and walk near or away from the device to complete the simulation operation process through human-computer interaction.

Learners can modify the device's status by manipulating various controls, including valves, handles, buttons, or switches. The device then provides feedback on its current state through auditory cues, visual indicators, and animated displays. Consequently, the status of the air system and related components within the platform, as well as the values of pertinent parameters, undergo changes. Incorrect manipulation of the controls will lead to abnormal feedback from both the system and the device.

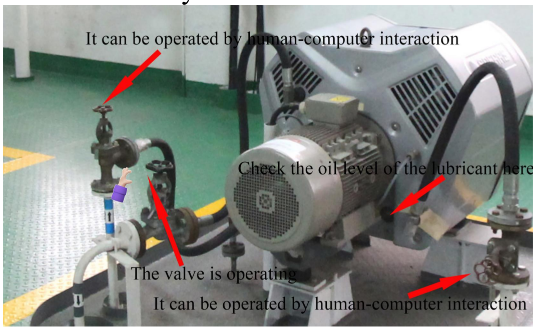

Figure 5. Air Compressor Simulation Operation Scenario

3.3.3 VR operations

The project team developed a binocular split-screen display mode suitable for VR glasses for VR operation, and optimized the scene and interactive operation. Intelligent prompt signs are added to guide learners to walk in the scene, find the operation points, and complete the practical training content, as shown in Figure 6. The initial state of these action points is determined by the business logic.

Learners can freely switch between normal mode and VR mode in all scenes of any submodule during simulation operation or VR operation. Learners can also click the VR operation button on the login interface of the teaching platform to enter the first scene of VR operation and start the complete VR operation.

Figure 6. VR Scene of Air Bottle Operation

Learners can use Cardboard devices and game controllers to walk and roam in the VR scene and complete various interactive operations, as shown in Figure 7. Triggering hot spots, activating controls, roaming, and operating devices can be realized by turning the head and other body movements combined with using the gamepad to issue commands.

When using mobile devices such as mobile phones to log in to the teaching platform, the gyroscope can be automatically or manually turned on to simulate and restore the original appearance of the actual operation site to the maximum extent, and simulate the feeling of learners in the land-based engine room. The VR operation module automatically turns on the gyroscope by default.

Figure 7. VR Operation of User

Different operations may lead to different results. The wrong operation will trigger the fault chain in the system, and the teaching platform will feedback the fault phenomenon and the resulting consequences to the learners.

If all operations are performed correctly, the systems and equipment in the land-based engine room on the platform will be in normal operating condition. Information such as operating procedures, changes in parameter values, various triggered events and alarms, and changes in the status of each system in the land-based engine room will be recorded in the database. These data can be fed back to the instructor through the assessment and feedback module, which is used to analyze and evaluate the rationality of the learners' operation process. The results of the data analysis can be used to improve and optimize the various functions of the platform.

4. Testing and Application of Platform

4.1 Stress Test of Platform

The land-based engine room educational and training platform has been deployed on the Alibaba Cloud ECS server, equipped with a 2-core CPU, 8G of memory, 5M bandwidth, and an ESSD cloud disk. Additionally, the server is configured with LAMP (Linux+Apache+Mysql+PHP) software.

For stress testing, Apache JMeter was utilized. The parameters were set as follows: 40 threads (or users), a ramp-up time of 5 seconds, 50 loops, continuous testing upon encountering errors, and listeners configured to view the results tree and aggregate report. The pressure test encompassed key operations within the practical training platform's operation module, specifically targeting the directory scene page, air compressor inspection scene page, air bottle operation scene page, control box operation scene page, and air bottle discharge residue scene page. A portion of the aggregate report's test data is presented in Table 1.

Table 1. Pressure Test Data of Platform

Content	Sample Requests	Average Response Time (ms)	Minimum Response Time (ms)	Maximum response time (ms)	Abnormal Responses (%)	Throughput (Transactions·s^{-1})
Directory Scene Page	2 000	768	245	2 416	0	185.3
Air Compressor Inspection Scene Page	2 000	835	272	2 696	0	158.1
Air Bottle Operation Scene Page	2 000	616	224	2 394	0	190.4
Control Box Operation Scene Page	2 000	552	189	1 994	0	239.7
Discharge Residue Scene Page	2 000	531	167	2 051	0	260.1
Total	10 000	660	167	2 696	0	180.2

4.2 Test Results and Analysis

Upon examination of the test results within the View Results Tree, it is evident that all sample requests exhibit green test results. This indicates that all server requests and responses were successfully executed, with all samples returning a response code of 200. Furthermore, there were no errors observed in any of the responses, and the response information for each was confirmed as "OK." These findings suggest that the practical training teaching platform functions without any apparent issues under the tested conditions.

At the time of testing, each request occurred 2,000 times. According to the data in Aggregate Report, the average response time of sample requests is 660 ms, the minimum is 167 ms, and the maximum is 2 696 ms. All requests have no abnormal response, and the overall throughput is 10.6 times/second. It can be seen that the practical training and teaching platform basically runs smoothly under the test conditions, and no significant time delay occurs when simulated users access the teaching platform and successfully perform relevant operations. The delay time of cloud teaching platform's response to requests does not affect the user's operating experience. The ECS server in this configuration can meet the needs of 40 users accessing the teaching platform in the same time period.

4.3 Application and Effect Analysis

Two classes (25 +19 learners) were selected from the undergraduate class of Marine Engineering Management of class 2018, and online practical training teaching platform was introduced to assist on-site teaching in the teaching of the land-based engine room practical training course in the first semester of 2021-2022. The assessment method of practical training course was still the traditional on-site assessment method. The learners' operation experience and learning effect were investigated by using five-level Likert scale. The questionnaire was filled in anonymously and voluntarily. A total of 40 valid questionnaires were collected. The survey results are shown in Table 2.

Table 2. Learners' Evaluation of the Platform

	Options (5 points for full compliance, 4 points for full compliance, 3 points for general compliance, 2 points for non-compliance, 1 point for complete non-compliance)	Mean Value	Standard Deviation
Experiences	Be able to quickly get familiar with the operating environment and operating objects.	4.51	0.61
	Feel the operation and interaction is relatively smooth.	4.03	0.79
	Feel the platform's cloud operation is convenient and flexible.	4.78	0.51
	Can quickly master the operation methods of each module of the simulation practical training teaching platform.	4.31	0.86
	Feel the function of the teaching platform is perfect.	4.48	0.52
	Learning on the platform is very efficient.	4.01	0.91
Effects	Achieved the expected learning objectives.	4.11	0.54
	The proficiency of on-site practice and the tacit understanding of cooperation had been significantly improved.	4.62	0.52
	Enhanced the confidence of on-site practical operation.	4.23	0.60
	Increased interest in practical training operations.	4.75	0.55
	Improved the ability of independent learning and the ability to solve engineering problems.	4.08	0.71

Upon analyzing the scale data, it is evident that the average rating for all options exceeds 4 points. This indicates a favorable evaluation by learners towards the functionality, user experience, and effectiveness of each module within the online practical training platform for land-based engine rooms. Notably, the option pertaining to the convenience and flexibility of the platform's cloud-based operations received the highest mean score of 4.78 with a relatively low standard deviation of 0.51. This suggests a widespread recognition among learners of the ease and adaptability associated with learning and operating on the cloud platform. Conversely, the option related to the efficiency of learning on the platform exhibited the highest standard deviation of 0.91. This variability could be attributed to differences in learning habits and adaptability to the platform's operational procedures among individual learners. Overall, learners express a keen interest in completing learning and simulation activities on the online practical training platform, with a particular appreciation for the realistic nature of the VR operations.

After the learning and simulation of the online training platform, the learners felt that the safety, accuracy, proficiency and efficiency of the on-site practical operation were greatly improved. In the teaching process, the instructor found that learners' tacit cooperation, initiative, self-confidence, teamwork ability and on-site problem-solving ability were significantly improved during field practice. This is basically consistent with the results shown by the scale data. After repeated practice of the online operation, the learners are familiar with the scene and skilled in the operation before the actual operation. In field practice, learners have understood what they want to do, how to do it, the order of doing it, and understood the purpose and significance of each step of operation, which directly improves the confidence of field practice.

Once the scoring process was completed, the educational administration management system disclosed that the mean scores for the practical training course of the land-based engine room, also known as the Marine Engineering Comprehensive Practical Training course, were notably high, with 83.84 and 86.32 for the two test groups respectively. These averages were superior to those of other cohorts at the same educational level. In line with ISO-9001 quality management system benchmarks, the project team scrutinized academic records of undergraduate students maintained by the Marine Engineering School of Dalian Maritime University. Their findings revealed that the average scores of the test groups outperformed those of the 2017 cohort and most cohorts preceding this course. Additionally, an analysis of on-site evaluation forms retained by each instructor, documenting scores for specific practical operations, indicated that the assessment scores for the Marine Engineering Comprehensive Practical Training course among the test groups were notably higher compared to other cohorts at the same level and those from previous years. This underscores the efficacy of integrating the online practical training platform of the land-based engine room with on-site practical operation instruction, resulting in a significant enhancement of the quality of practical training instruction.

5. Conclusions

The integration of cutting-edge technologies like VR, panoramic interaction, and cloud services with the land-based engine room training for marine engineering management has been achieved through the advancement and implementation of the land-based engine room online training platform. This innovation effectively addresses various shortcomings in the practical training programs offered by Dalian Maritime University.

Simulation stress tests conducted on the platform indicate that it currently supports smooth access and interactive cloud operations for up to 40 concurrent users. By supplementing on-site practical training, the online platform has demonstrated notable improvements in the efficiency and quality of learners' practical learning experiences, leading to favorable outcomes and positive feedback from users.

The development and application of this online simulation practical training platform mark a significant milestone in bridging the gap in the application of panoramic interactive technology within marine engineering education in China. It offers valuable insights for institutions seeking to construct high-caliber, shared online practical training resources, embrace innovative "intelligent plus" teaching models, and facilitate the integration of next-generation information technologies in education, thereby propelling educational reform. This transformation aligns with China's broader ambition to evolve from a major player in engineering education to a leading force in the field.

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