Construction and Application of Waterway Engineering Design Virtual Simulation Cloud System Based on Outcome-Based Education

https://doi.org/10.3991/ijet.v17i20.31355

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Abstract—Hydraulic design is automatically inherent in hydraulic engineering courses, conventional teaching of the Waterway Engineering Design course tends to have limitations such as low participation, poor interactivity, disconnection between theoretical and experimental training, and restriction of experimental design by time and space. To address these needs, a virtual simulation cloud system of Waterway Engineering Design is developed based on outcome-based education. Taking real engineering projects as prototypes, this system adopts virtual reality technology and cloud platform to simulate the scene structure and instrument function with high precision. The multi-model, integrational teaching expands the experimental content, enhances the interactivity of the design process, and provides a high-quality, immersive online learning experience for students. Since its application, the Waterway Engineering Design Virtual Simulation Cloud System has received good feedback from both teachers and students. During the Covid-19 epidemic, it provided significant support for experiments and teaching of the Waterway Engineering Design course and became a pivotal supplement to the existing teaching system. The Waterway Engineering Design Virtual Simulation Cloud System adheres to the "student-centered" teaching principle, builds up students' ability for independent learning and engineering practice, and facilitates their personal development and training for excellent engineers.

Keywords—waterway engineering, outcome-based education, virtual simulation, cloud platform

1 Introduction

A new round of science and technology and industrial revolution worldwide is driving the formation and development of new economy [1]. Accordingly, engineering education reform in universities has received unprecedented attention [2]. The recent economic growth and the latest round of scientific and industrial revolutions have posed new challenges to the transformation and development of engineering education [3, 4]. Since the end of the 20th century, international engineering education reform has been in full swing, with slogans such as "return to engineering", "paradigm shift of engineering education" and "reengineering engineering education", all reflecting the international development trend of engineering education [5, 6]. Both the NEET plan proposed by MIT and the "New Engineering" policy proposed by the Chinese government advocate that engineering education should be transformed from engineering science paradigm to engineering practice paradigm, with the goal of cultivating engineering talents with solid engineering practice ability, so that engineering education can return to the essence of engineering practice [7].

Since 2019, with the global pandemic of Covid-19, educational institutions around the world have been closed to varying degrees. Under these circumstances, students and teachers are transitioning to distance learning [8, 9]. As shown in Figure 1, according to UNESCO's global statistics on February 28, 2022 [10], educational institutions in more than 200 countries worldwide have been affected by the epidemic. The daily lives of teachers and students have changed dramatically during the shutdown. Meanwhile, with the rapid development of Internet of Things (IoT) technology, cloud platform technology and mobile Internet technology, the Internet technology is profoundly changing the face of education, pushing education toward digitalization, networking and intelligence, which to a certain extent solving the difficulties of online teaching [11–13]. Therefore, considering that the epidemic will not change dramatically in the short term, it is essential to apply the educational concepts of New Engineering and NEET to the practical teaching of Waterway Engineering Design with the help of rapid development of Internet technology [14].

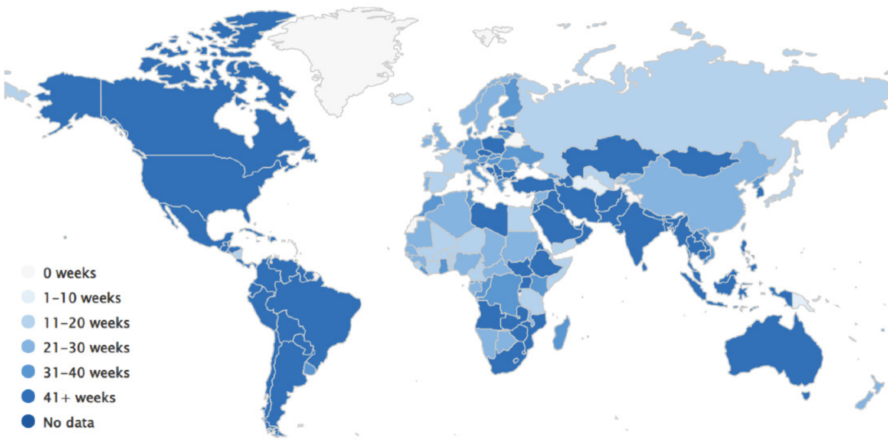

Fig. 1. The total length of school closures in countries around the world

The Waterway Engineering Design is a highly practical professional course. The main tasks of the course include the introduction of the characteristics of rivers and waterways, the content, classification and design principles of waterway improvement projects, waterway dredging projects and waterway channelization projects, and the design of water transportation projects and navigable buildings. China's water resources are unevenly distributed in time and space, and the construction of new waterway engineering requires many high-level professionals with engineering practice ability, so the teaching of the course "Waterway Engineering Design" has faced challenges [15].

The Waterway Engineering Design mainly adopts the teaching method of theoretical learning through videos, pictures, oral statements, etc., combined with offline course design and professional practice to strengthen the understanding of theoretical courses. This method focuses more on knowledge transfer and less on ability cultivation, and often puts the transfer of knowledge at the center of teaching. There are three levels of confusion among teachers and students in this teaching environment. First, there is a severe lack of situational education. The actual engineering often exists in three-dimensional form in real space, and it is difficult to restore the application of real engineering scenarios simply by video, pictures, oral narration, etc. In this case, students have insufficient imagination, feeling that the course is heavy and boring, cannot keep up with the teaching progress, and the practical sessions are ineffective [16]. Second, theoretical teaching is often separated from engineering practice [17]. The teaching arrangement of the Waterway Engineering Design course at Tongji University is shown in Figure 2. In the limited time of the classroom, most credit hours are used for theoretical knowledge lectures, and only a tiny part of the credit hours are used for discussion, design and practice. Under this situation, it is difficult for students to establish engineering design ideas and get substantial engineering design training. Constrained by the traditional teaching mode, teachers have difficulties in broadening their thinking. With the existing media, it is difficult to explain the layout characteristics, structural characteristics, mechanical performance calculation and construction technology of navigation channel projects such as ship lock and breakwater. Third, the communication between teachers and students has more significant limitations. In the actual teaching process, teachers and students mainly communicate with each other through classroom interaction or off-class answers to difficult points in the course, and the communication time and place are limited to the classroom, which further leads to the poor learning and understanding effect of students.

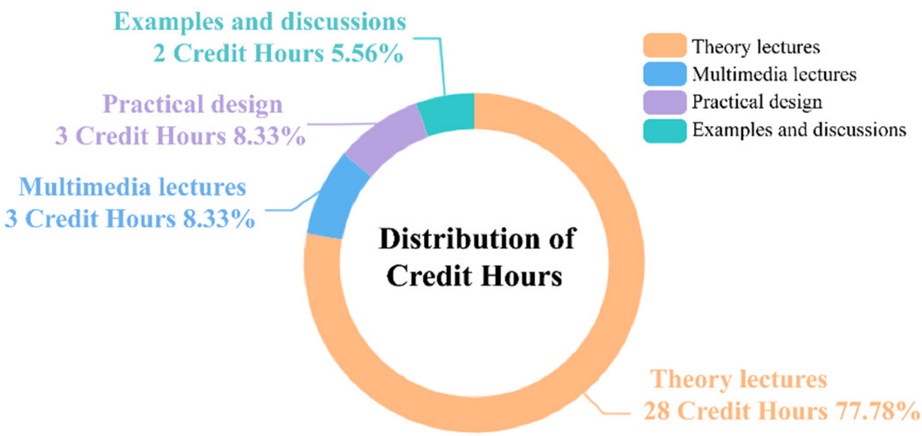

Fig. 2. Distribution of credit hours of Waterway Engineering Design course at Tongji University

As an education based on students' specific learning strengths, outcome-based education drives the operation of the education system with students' output, which can well mobilize students' enthusiasm and improve students' level. Thus, in order to cope with the above unfavorable factors affecting the teaching quality and to cultivate future engineers who are capable of solving practical engineering problems, this study develops a Waterway Engineering Design Virtual Simulation Cloud System (WEVS cloud system) based on outcome-based education to cultivate students' engineering practice ability and innovation consciousness by improving their knowledge application and hands-on ability. Taking the complex and difficult-to-understand breakwater layout design and ship lock structural design in the Waterway Engineering Design course as an example, combining virtual simulation technology and big data cloud platform technology, and using OBE (outcome-based education) as the guiding ideology, we put forward the idea of education and teaching reform of engineering course design based on student-centered and problem-solving-oriented virtual simulation technology, and establish a new teaching system of "exploratory" learning for students and "pointing" guidance for teachers, so as to promote the online and offline integration construction of the Waterway Engineering Design course [18, 19].

2 Methodology

In the development process of the WEVS cloud system, it is no longer limited to the inherent thinking in teaching, but adopts the outcome-based education (OBE) concept, which focuses on cultivating students' ability to transform academic knowledge into practical engineering problem-solving. Besides, the system is oriented to the needs of society and uses engineering education accreditation standards as a guiding plan, striving to make students the center of instruction.

2.1 OBE concept

The OBE concept first appeared in the United States and Australia in the early 1990s [20]. OBE is a reverse design based on goal-oriented training, which can propose a specific talent development program according to different student qualities, learning environments, and learning goals, and the program includes a curriculum system and an evaluation system [21, 22]. In an OBE system, everything is organized and built around clear learning objectives to ensure that it is genuinely student-centered, so that students can have the knowledge, ability and quality they need to succeed at the end of their education. Based on the OBE mode, the WEVS cloud system reversely designs the teaching objectives according to students' graduation requirements, introduces the virtual simulation experiment into the experimental and practical teaching process of the Waterway Engineering Design course. It combines the theoretical knowledge of the course with the actual engineering projects, takes the experimental simulation projects as the carrier, reconstructs the teaching contents, and leads students to independent learning and collaborative learning.

2.2 Design of WEVS cloud system

Technically, unlike traditional experimental platforms, the WEVS cloud system has more possibilities and convenience under the aegis of cloud platform technology. Cloud platform, also known as cloud computing platform, is a service based on hardware and software resources to provide computing, networking and storage capabilities [23, 24]. As illustrated in Figure 3, the cloud platform can unify the management of virtualized computing resources, storage resources, and network resources, and provide services to users to form cloud services. Users can upload data content to the cloud platform server, which performs system management, intelligent interaction, implementation transmission and resource performance monitoring, as well as cloud computing, complete domain immersion and congestion control, etc. The interactive content experience is delivered to various forms of client terminals through 4G/5G and gigabit LAN, etc. Students can participate in the virtual experiment process anytime and anywhere through portable and popular devices such as cell phones and pads, truly realizing the open sharing of the system.

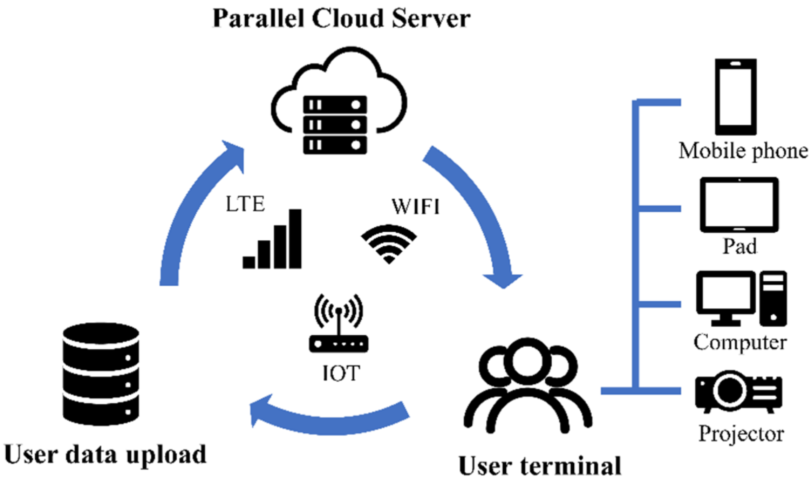

Fig. 3. Cloud platform service process

In terms of content, the virtual simulation experiment cloud system contains the traditional experimental safety guidance, process demonstration and explanation, results processing report, etc. In addition, the system uses the solid immersive interactive experience of the computer software, the highly personalized, time-space-independent operation method, and the realistic simulated operation environment to give students a more immersive experience. When the teacher puts forward the design requirements, students can explore with their imagination and creative abilities using the virtual simulation system with questions. In this process, they can gradually grasp the essence of the principles, achieve better understanding and design more suitable and excellent works. The introduction of virtual simulation experiments helps carry out practical teaching based on OBE mode. And the organic combination of the two can better solve the common and individual problems in the practical teaching link of the Waterway Engineering Design course, and comprehensively cultivate students' independent learning ability, innovation consciousness and engineering practice ability.

Function modules. As demonstrated in Figure 4, the WEVS cloud system contains two main modules. The first module is the experiment and layout design of breakwater, and the second module is the experiment and structural design of ship lock. Each module contains three major systems: theory teaching, design operation, and homework grading. For students, the theory teaching system includes experimental teaching awareness, rules and regulations explanation platform, the design operation system comprises step-by-step design explanation, design display platform, and the homework grading system involves an assignment submission platform. For teachers, the theory teaching system incorporates a content update processing platform, the design operating system includes a design process feedback, a message interaction platform, and the assignment grading system contains an assignment access platform.

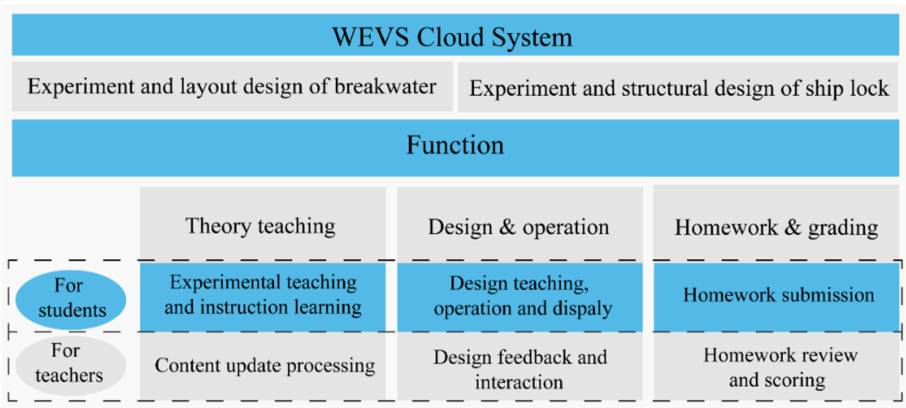

Fig. 4. The architecture diagram of the WEVS cloud system

The WEVS cloud system fully integrates the concept of OBE teaching. After logging into the breakwater or ship lock module, students enter the theoretical knowledge stage with questions and the target requirements of the design. According to the teaching concept of OBE, virtual simulation, experimental teaching animation, test videos, etc., are integrated into the teaching process, which makes students feel fresh and interested in experimental teaching. Also, the instructor-led course format can be changed to a student-centered laboratory course, so that students are fully aware of the information requirements and regulations related to the experiment and thus have some basic understanding of the problem to be solved and the objectives to be accomplished. After that, the students enter the experimental design and operation stage to seek rules, explore results, and develop abilities. With the website's assistance, students can independently consult relevant literature, set the parameters of the components, specify the corresponding experimental rules, and then explore the virtual simulation experiments for different reference conditions. Thus, the best quality data results can be found through multiple experiments and applied to the model design to fully develop students' independent operation and innovation ability. Finally, the self-designed model is presented and the text is written and submitted in the homework evaluation system, truly teaching people to fish rather than receiving fish, thus completing the whole teaching process by integrating the OBE concept. In the process of solving the set problem, students master a lot of practical skills, and at the same time, they gradually learn and consolidate their theoretical knowledge, and cultivate students' practical engineering ability and self-exploration ability, and fully stimulate their enthusiasm and motivation. Moreover, teachers can update theoretical experimental teaching contents, design operation instructions and handle student information directly after logging into the system. By accessing different boards, teachers can give feedback on students' assignments, form effective communication between teachers and students and improve students' learning efficiency.

Model construction. The system adopts 3D modeling simulation technology, applying Unity3D and 3D Studio Max and other technologies to simulate the experimental components, environment, and functions. Moreover, the system uses the smooth particle hydrodynamics method (SPH) to simulate the water motion with high precision, providing students with a good immersion and exploration experience [16]. Figure 5a shows the port model in the breakwater module, the whole port contains three parts: wharf, land area, and port water, the port water is divided into the anchorage, harbor pond, channel, and gyratory water, in addition, the breakwater and the port gate are set in the lower part of Figure 5a. The overall diagram of the ship lock model is shown in Figure 5b. The ship lock contains many structures: the upstream approach channel, the upper lock head, the lock chamber, the lower lock head, and the downstream approach channel. Through the video explanation roaming and the bird's eye view and partial enlargement, the details of each part of the model structure can be fully displayed, bringing a better immersive interactive experience and thoroughly stimulating students' interest and independent learning ability.

(a) (b)

Fig. 5. (a) Model of breakwater, (b) Model of ship lock

Operation steps and results display.

The experiment and layout design of breakwater. After logging in the website, there is the interface of the experiment and layout design of breakwater. which comprises of three modules: port introduction, design guide, and breakwater layout design. As shown in Figure 6, in the introduction part of the port, the bird's-eye view and roaming display are used to display the supporting facilities of the port. Meanwhile, the phonetic explanation provides students with a better grasp of theoretical knowledge and an immersive experience.

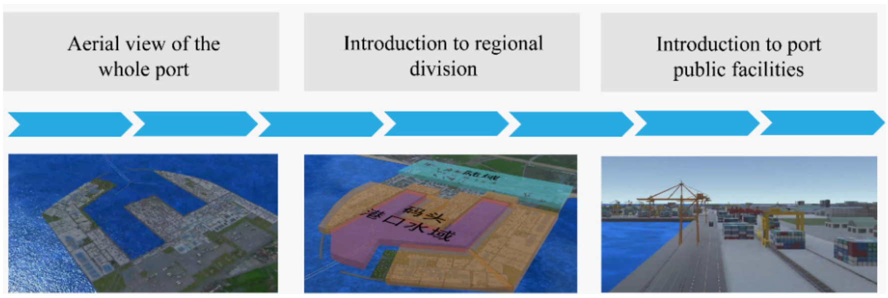

Fig. 6. Introduction to the roaming display of the port and breakwater

At the hub page, the design tasks, design information, design specifications, relevant calculation formulas, and construction requirements for the breakwater are shown in detail. The design book is formatted according to the policies and regulations required for the actual project, allowing students to get a preliminary understanding for the entire design process of the existing scheme in advance.

In the section of breakwater layout design, it is divided into several modules, such as experimental parameter setting, measurement point arrangement, data collection, result analysis, and breakwater layout design. After having a particular understanding of the port design, students can freely fill in the reasonable direction and width of the port gate concerning the data given, such as the design water depth, wave height, period, strong wave direction and breakwater form. As depicted in Figure 7, when the filled data meet the specification requirements, the ship can berth into the port and the system interface enters the collection points arrangement, while when the data set is not reasonable, the page will feedback to remind to reset the appropriate parameters. Next, following the prompts, detectors can be set up at multiple measurement points. Each detector can display the wave height of this point at the beginning of the wave, and can form the comparison of the effective wave height of various measurement points. By analyzing the data, students can judge the validity of the data. If they think the data is defective, they will return to the experiment again. If they believe the data works well, they will save the data and apply the appropriate data to the design module of the breakwater entrance and structure.

Finally, students can generate an experimental design report under the multidimensional evaluation system of knowledge exploration, experimental practice, and engineering design by integrating all the contents. Thus, comprehensive feedback on students' understanding and ability can be formed, which ensures that students can truly master the theoretical knowledge they have learned.

Fig. 7. The process of breakwater experiment and design

The experiment and structural design of ship lock. Once students enter the experiment design interface of the ship lock, they will see a menu bar containing sections such as lesson plan view, design and design guide, assignment submission, and message view. As presented in Figure 8, students can independently view each part of the ship lock's detailed structure in the lesson plan view section. The site displays intellectualized and visualized lock scenarios containing information on the upstream approach channel, upper lock head, lock chamber, lower lock head and downstream approach channel. Students can set roaming observation perspectives, experience the scene with high authenticity and better understand the ship lock structure.

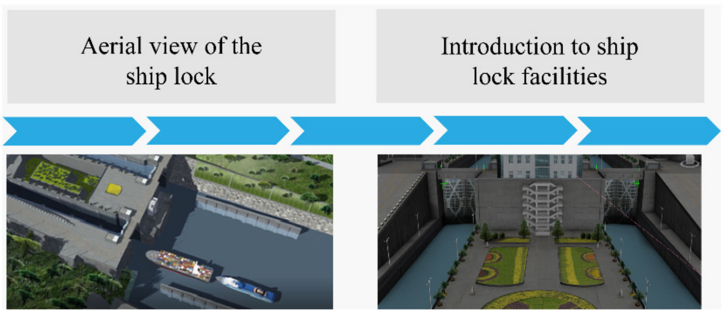

Fig. 8. Introduction to the roaming display of the ship lock and detailed structure

After the real-like experience of the cognitive teaching platform, students understand the structural details of the upstream approach channel, the upper lock head, the lock chamber, the lower lock head and the downstream approach channel; then, they will enter the design operation phase. In the design operation stage, the content of the ship lock design is fragmented and decomposed, and the design forms, design points and relevant design specifications are refined to form a knowledge evaluation module, which students can use for self-testing and self-restraint. Figure 9 presents the schematic diagram of the ship lock design. Based on the design information, students can follow the plant design process to select the structural type of the lock components, design the water transmission system, and calculate the structural stability. Any difficulties encountered in the design process can be fed back to the teacher through the interactive message window in the platform to get timely answers from the teacher. The data results obtained by the students through calculation and design and through BIM modeling software such as Revit to build the 3D model of the designed ship locks will eventually form a complete calculation report, which will be uploaded to the system through the assignment submission platform. After this, the teacher can give feedback on the validity and feasibility of the students' design by checking their design works and providing appropriate scores.

Fig. 9. The process of ship lock experiment and design

3 Results and discussions

As shown in Table 1, based on five evaluation criteria: strongly disagree, disagree, agree, quite agree, and strongly agree, the level of students' understanding of the WEVS cloud system based on OBE incorporated in the Waterway Engineering course is discussed and compared.

Table 1. Statements related to the application of WEVS cloud system with OBE concept

Statement	Descriptions
1	Students' scores comparison
2	Promoting users' experience
3	Improving users' understanding ability
4	Cultivating users' independent design ability
5	Transforming students into active learners

Figure 10a illustrates the comparison of students' performance using the traditional teaching method and the teaching method using the WEVS cloud system with the OBE concept. The graph is plotted and analyzed with the scores as horizontal coordinates and the number of students in each score range as vertical coordinates. Using a score band of 5, we can see that the number of students using the WEVS cloud system has a tremendous advantage in the score band above 85, and their scores are mainly distributed in the score band of 80–95, while students using traditional teaching methods have their scores primarily concentrated in the score band of 75–90. Figure 10b presents the normal distribution curve based on the distribution of the number of students in different score bands. The average score of students using the WEVS cloud system is 85.7, which is 3.1 points higher than the average score of 82.6 in the traditional method. The p-value for the data before and after using the WEVS system was 7.9%, with a trend towards significance to some extent. Although the mean score difference was not very large, students who used the WEVS system had a better learning experience. Furthermore, the peak of the vertical coordinate of the fitted curve for students using the WEVS cloud system is also higher than that of the conventional method, indicating that students' performance is better overall than that of the traditional method.

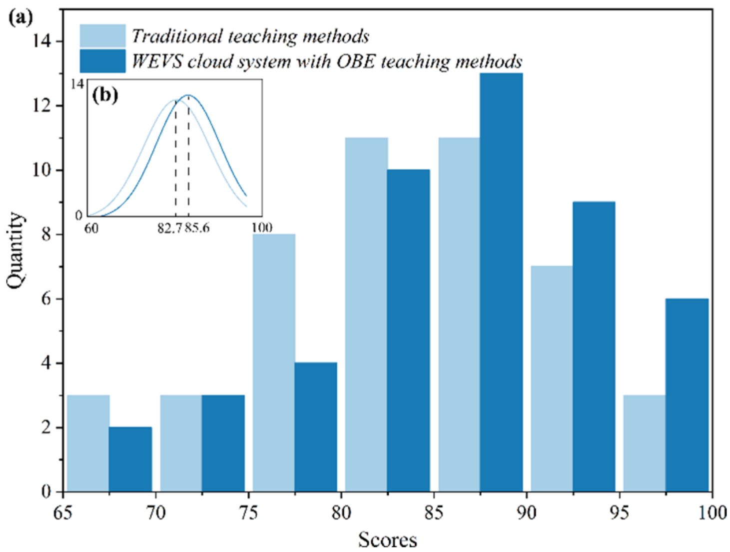

Fig. 10. Comparison of students' scores under traditional teaching methods and WEVS cloud system based on OBE

Figure 11a shows the Likert chart about the recognition of the WEVS cloud system on enhancing students' experience, from which it can be seen that 78.73% of students agree that the WEVS cloud system brings better user experience and can bring more comfortable interaction feeling. Figure 11b shows the recognition rating of the WEVS cloud system to improve students' understanding. More than 80% of students agree that the WEVS cloud system can bring a better understanding of knowledge. Through the WEVS cloud system, abstract learning can be transformed into concrete rich and detailed video and picture presentation, and students can deeply experience and understand the connotation of the Waterway Engineering Design course, grasp more details of the structure, and gain more knowledge of content.

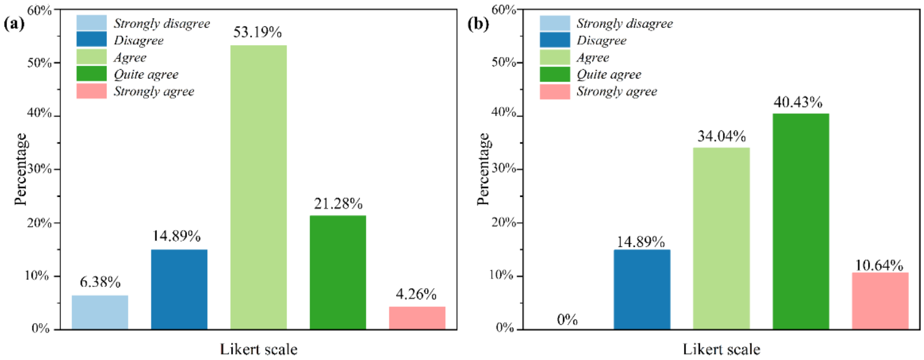

Fig. 11. Percentage frequency on the level of agreement on WEVS cloud system based on OBE in (a) promoting users' experience; (b) improving students' understanding ability

Figures 12a and b show the graphs of the recognition evaluation of the WEVS cloud system for developing students' ability to design independently and developing students' ability to become lifelong active learners. Figure 12a shows that 85.1% of students believe that the WEVS cloud system has developed their independent design skills, while Figure 12b shows that 80.85% of students believe that the WEVS cloud system has increased their learning initiative and can help them become active learners in the future. In the WEVS cloud system, students are encouraged to explore and exchange questions on their own in solving design problems to complete given tasks and projects. Through this process, students can develop their design skills and initiative, and ultimately become active learners. It can inspire students when they encounter new design problems in the future, giving full play to their ability to solve them independently, stimulating their motivation and improving their overall capabilities.

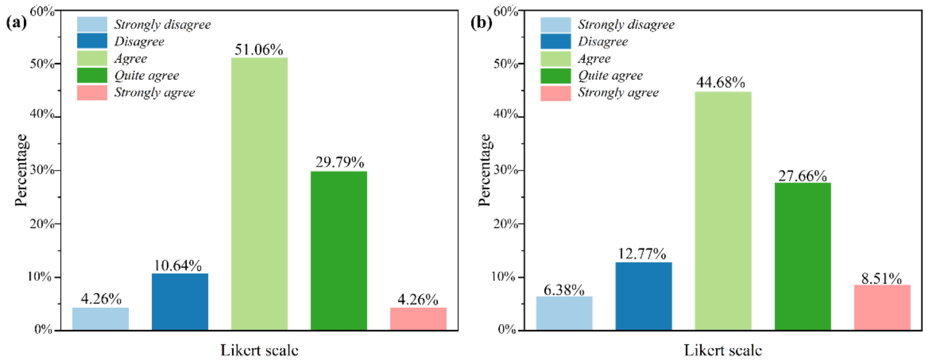

Fig. 12. Percentage frequency on the level of agreement on WEVS cloud system based on OBE in (a) cultivating students' independent design abilities; (b) transforming students into active learners

4 Conclusion

Laboratory teaching is crucial for students to master their professional skills and help them apply their theoretical knowledge to actual practice. The proposed WEVS cloud system integrates advanced cloud platform technology and virtual simulation technology with OBE-based teaching methods to provide students with a new model of content-rich, highly accurate and interactive experimental teaching. After the teaching promotion and application of the WEVS cloud system, the teaching effect is excellent. It not only enhances the ability of students to participate interactively in the whole process of the experiment, but also strengthens the observation and learning ability of experimental phenomena, which significantly makes up for the shortage of offline experimental teaching. The WEVS cloud system fully exercises the students' capabilities of independent exploration, independent thinking and independent problem solving, in addition to the ability to enhance the students' subjective initiative, its convenient and fast interaction, during the epidemic reflects the enormous advantages of online education, which shows that the construction of virtual simulation experiments is the inevitable path of experimental teaching reform in the new era. Although the WEVS cloud system has been continuously improved and iterated, there are still many shortcomings. In the future, the system will develop more experimental modules in Waterway Engineering Design and introduce actual engineering project experiments. At the same time, more virtual simulation experiment practice courses will be gradually established in the course of Waterway Engineering Design to help students develop personalized and train excellent engineers.

5 References

[1] M. Javaid, A. Haleem, R. Vaishya, S. Bahl, R. Suman, and A. Vaish, "Industry 4.0 Technologies and Their Applications in Fighting COVID-19 Pandemic," *Diabetes & Metabolic Syndrome-Clinical Research & Reviews,* vol. 14, no. 4, pp. 419–422, Jul–Aug 2020, https://doi.org/10.1016/j.dsx.2020.04.032

[2] M. M. Seke, "Would We Be Able to Absorb the New Normal Brought by COVID-19 as Another Educational Revolution?" *International Journal of Advanced Corporate Learning (iJAC),* vol. 13, no. 4, pp. 68–92, 2020, https://doi.org/10.3991/ijac.v13i4.16525
[3] M. Huda, A. Maseleno, M. Shahrill, K. A. Jasmi, I. Mustari, and B. Basiron, "Exploring Adaptive Teaching Competencies in Big Data Era," *International Journal of Emerging Technologies in Learning,* vol. 12, no. 3, pp. 68–83, 2017, https://doi.org/10.3991/ijet.v12i03.6434
[4] M. Huda *et al.*, "Big Data Emerging Technology: Insights into Innovative Environment for Online Learning Resources," *International Journal of Emerging Technologies in Learning,* vol. 13, no. 1, pp. 23–36, 2018, https://doi.org/10.3991/ijet.v13i01.6990
[5] X. Li, Y. Wang, and L. Zhang, "Research on How to Cultivate Qualified Personnel in Polytechnic College," in *2nd ETP/IITA Conference on Telecommunication and Information*, Phuket, Thailand, 2011; Apr 03–04 2011, pp. 1–3, doi: 10.1109/m2rsm.2011.5697413. [Online]. Available: <Go to ISI>://WOS:000290971800001
[6] W. Kuang, H.-L. Tian, L.-H. Fu, D.-L. Liu, and I. Destech Publicat, "Developing an Innovative and Creative Teaching Model for Engineering Education of College in China," in *4th International Conference on Education Reform and Modern Management (ERMM)*, Thailand, 2017; Aug 06–07 2017, in DEStech Transactions on Social Science Education and Human Science, 2017, pp. 1–5. [Online]. Available: <Go to ISI>://WOS:000445444700001
[7] P. Wang *et al.*, "Course Construction and Thinking on Knowledge Framework of Modern Electrical Engineering Education for Non-electrical Engineers Facing Emerging Engineering Education," *Zhongguo Dianji Gongcheng Xuebao/Proceedings of the Chinese Society of Electrical Engineering,* vol. 41, no. 11, pp. 3730–3740, 2021, https://doi.org/10.13334/j.0258-8013.pcsee.210158
[8] K. Mukhtar, K. Javed, M. Arooj, and A. Sethi, "Advantages, Limitations and Recommendations for Online Learning During COVID-19 Pandemic Era," *Pakistan Journal of Medical Sciences,* vol. 36, no. 4, pp. S27–S31, May 2020, https://doi.org/10.12669/pjms.36.COVID19-S4.2785
[9] B. L. Moorhouse, "Adaptations to a Face-To-Face Initial Teacher Education Course 'Forced' Online Due to the COVID-19 Pandemic," *Journal of Education for Teaching,* vol. 46, no. 4, pp. 609–611, Aug 7, 2020, https://doi.org/10.1080/02607476.2020.1755205
[10] Unesco. https://en.unesco.org/covid19/educationresponse (accessed 2.28, 2022).
[11] K. A. A. Gamage, D. I. Wijesuriya, S. Y. Ekanayake, A. E. W. Rennie, C. G. Lambert, and N. Gunawardhana, "Online Delivery of Teaching and Laboratory Practices: Continuity of University Programmes during COVID-19 Pandemic," *Education Sciences,* vol. 10, no. 10, Oct 2020, Art no. 291, https://doi.org/10.3390/educsci10100291
[12] C. Carrillo and M. A. Flores, "COVID-19 and Teacher Education: A Literature Review of Online Teaching and Learning Practices," *European Journal of Teacher Education,* vol. 43, no. 4, pp. 466–487, Aug 7, 2020, https://doi.org/10.1080/02619768.2020.1821184
[13] A. M. Al-Abdullatif, A. A. Al-Dokhny, and A. M. Drwish, "Critical Factors Influencing Pre-Service Teachers' Use of the Internet of Things (IoT) in Classrooms," *International Journal of Interactive Mobile Technologies (iJIM),* vol. 16, no. 4, pp. 85–102, 2022, https://doi.org/10.3991/ijim.v16i04.27007
[14] H. Cong, X. Hu, Y. Xu, Q. Li, and H. Zhao, "Innovation-Oriented Curriculum Teaching Practice on Fundamental Theory of Electrical Engineering Course With Experiment First and Then Theory," *Zhongguo Dianji Gongcheng Xuebao/Proceedings of the Chinese Society of Electrical Engineering,* vol. 41, pp. 401–410, 2021, https://doi.org/10.13334/j.0258-8013.pcsee.210718

[15] Y. Jiang, "China's Water Scarcity," *Journal of Environmental Management,* vol. 90, no. 11, pp. 3185–3196, Aug 2009, https://doi.org/10.1016/j.jenvman.2009.04.016
[16] C. Shen, B. Zhang, S. L. Yan, and X. L. Fu, "Cloud-Based Virtual Simulation System of Wave Motion Characteristics," *Computer Applications in Engineering Education,* vol. 30, no. 2, pp. 609–627, Mar 2022, https://doi.org/10.1002/cae.22476
[17] Y. Liu, H. Chen, L. Gao, C. Guo, L. Yuan, and Y. Qiao, "Design and Application of Interactive Simulational-Experimental Teaching System of Virtual Shipyard and Marine," *Research and Exploration in Laboratory,* 2019.
[18] K. Premalatha, "Course and Program Outcomes Assessment Methods in Outcome-Based Education: A Review," *Journal of Education-Us,* vol. 199, no. 3, pp. 111–127, Oct 2019, https://doi.org/10.1177/0022057419854351
[19] M. Zheng, C.-C. Chu, and Y. J. Wu, *Online-to-Offline Teaching Reform in China: Outcomes-Based Education* (Future of Innovation and Technology in Education: Policies and Practices for Teaching and Learning Excellence). 2019, pp. 237–252. https://doi.org/10.1108/978-1-78756-555-520181018
[20] R. M. Harden, J. R. Crosby, and M. H. Davis, "AMEE Guide No. 14: Outcome-Based Education: Part 1 – An Introduction to Outcome-Based Education," *Medical Teacher,* vol. 21, no. 1, pp. 7–14, Jan 1999, https://doi.org/10.1080/01421599979969
[21] A. M. Morcke, T. Dornan, and B. Eika, "Outcome (competency) Based Education: An Exploration of its Origins, Theoretical Basis, and Empirical Evidence," *Advances in Health Sciences Education,* vol. 18, no. 4, pp. 851–863, Oct 2013, https://doi.org/10.1007/s10459-012-9405-9
[22] M. M. Chabeli, "Higher Order Thinking Skills Competencies Required by Outcomes-Based Education from Learners," *Curationis,* vol. 29, no. 3, pp. 78–86, Aug 2006, https://doi.org/10.4102/curationis.v29i3.1107
[23] I. A. T. Hashem, I. Yaqoob, N. B. Anuar, S. Mokhtar, A. Gani, and S. U. Khan, "The Rise of "Big Data" On Cloud Computing: Review and Open Research Issues," *Information Systems,* vol. 47, pp. 98–115, Jan 2015, https://doi.org/10.1016/j.is.2014.07.006
[24] S. Singh, N. Saxena, A. Roy, and H. Kim, "A Survey on 5G Network Technologies from Social Perspective," *IETE Technical Review,* vol. 34, no. 1, pp. 30–39, 2017, https://doi.org/10.1080/02564602.2016.1141077

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Article submitted 2022-04-01. Resubmitted 2022-07-26. Final acceptance 2022-07-26. Final version published as submitted by the authors.