Teaching Practices of a Warehousing Management Curriculum Based on Virtual Reality Simulation Technology

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Abstract—Warehousing management is a specialized core curriculum in the logistics management major. The curriculum not only teaches strong theoretical concepts, but also practical skills. Traditional teaching mode emphasizes on theoretical teaching due to the lack of sufficient practical conditions; hence, students' practical abilities cannot be developed comprehensively. Therefore, this study proposed teaching reform measures, such as reconstructing the curriculum content, implementing modularized teaching, and creating a build-task-exercise-evaluation teaching mode by introducing virtual reality (VR) simulation technology and improving the teaching method. With these measures, students could finish their tasks and realize their learning objectives in the virtual intelligent warehouse environment by combining the knowledge and skills they have learned. Moreover, students were asked to design a warehouse layout by using the simulation software according to enterprise case data. Results show that the task-driven teaching reform for warehousing management curriculum based on VR technology improves the efficiency and quality of students' skill training.

Keywords—VR simulation technology, warehousing management, teaching reform, work task

1 Introduction

Modern logistics is a composite industry that provides users with multi-functional and integrated comprehensive logistics services through organic combination of traffic and transportation, warehouse, loading and unloading, distribution processing, delivery, and information processing. Warehousing management is the key link in modern logistics industry and training warehousing management technologies. Thus, developing students' skills is one of the objectives of talent training in the logistics management major in higher vocational colleges. With the application of concepts and technologies like Internet + Logistics, Internet of Things (IoT), cloud computing, artificial intelligence, big data, and block chain in the logistics industry, traditional logistics industry has advanced toward intelligent logistics continuously. As a result, the logistics industry becomes intelligent, standardized, flexible, digitalized, and

automated. Hence, development of intelligent warehousing is an essential trend. Intelligent warehousing is a new branch of warehousing management that is produced under applications of new logistics technological applications. Intelligent logistics is realized through informatization, IoT, and mechatronics. These technologies lower warehouse costs, improve operational efficiency, and increase warehousing management ability. Express enterprises like Jingdong Logistics and S.F. Express have built and explored the use of unmanned warehouses to meet small-sized and multi-batch logistics distribution needs. Manufacturing enterprises like Haier and Gree have also built automatic warehousing systems combined with intelligent manufacturing to meet automatic and intelligent needs of the manufacturing and assembly process. This development trend will bring unprecedented challenges to the professional talent training of high-quality technological and skills-oriented intelligent logistics in vocational education.

Warehousing Management is a core specialized curriculum in the logistics management major in higher vocational colleges. The curriculum covers warehousing system plan, warehouse operation management, and inventory control, among other subjects. Its primary objective is to train students in designing and executing warehouse-delivery integrated logistics operation schemes as well as their operation management abilities and professional qualities in core logistics matters. The curriculum is offered to meet the talent demands for intelligent warehousing management. Warehousing Management has strong practical properties. The principles, methods, and skills covered in this curriculum are based from logistics enterprises and have been used by logistics enterprises in operation production practices. Warehousing management is more difficult to teach than ordinary management curricula. The current logistics teaching method emphasizes on theoretical teaching, which is manifested as lectures and theoretical exams. However, this teaching mode lacks innovation. Although many teachers have been exploring teaching modes based on working process and task-driven teaching mode, they have difficulty stimulating the interest, enthusiasm, and creativity of students because they cannot build real enterprise operation environments. To make the teaching process serve better the enterprise demand for capable manpower and train high-quality technology-oriented talents for intelligent logistics management, the curriculum content, teaching philosophy, and teaching method of Warehousing Management must be undergo reform and innovation.

2 State of the art

Many scholars in the world have explored the application of 2D simulation technology, 3D technology, and virtual reality (VR) technology in the field of education, and the integration with the teaching of logistics management curriculum. For example, Nawaila, M. B et al. (2017) found that these technologies integrating technological enhancement and support for learning had impacted the field of education [1]. Ahmad, A. S et al. (2021) pointed out that 3D technology provided students with a more comprehensive perspective, facilitates the transmission of

information to students, and improved the learning process [2]. Boettcher, K et al. (2021) identified the benefits of virtual reality (VR) used in teaching conser-vation laws [3].Barjis, J et al. (2012) proposed a selection of a simulation software when solving logistics supply chain problems[4]. Liou, et al. (2018) provided students with an integrated virtual learning environment by combining VR technology, VR equipment, and 3D interactive virtual digital resources to help them improve their academic achievements and learning motivations [5]. Huang, Z et al. (2016) proposed an experimental teaching mode of VR simulation and carried out an experimental process design for warehouse sorting links. Results showed that this teaching mode could effectively train students' ability in problem analysis and solving by using professional knowledge in logistics [6]. Cao, X et al. (2019) built an automatic warehouse operation simulation system by using Flexsim software. They finished a simulation optimization of the in–out system of warehouses and provided a VR warehousing system simulation experimental platform [7]. Zhao, C(2019) reconstructed the knowledge system of warehousing and delivery management by using a 3D simulation teaching method, which increased the practical engineering ability of students effectively in the production operation environment [8]. Chen, Z (2021) carried out layered experimental design and teaching practice schemes on the basis of a virtual simulation platform and provided specific teaching cases [9]. Yang, Y et al. (2021) suggested to build an unmanned warehousing teaching and training platform based on AGV and designed an unmanned warehousing operation and plan simulation, big data, and other training systems through the VR teaching mode [10]. Zhang, G et al. (2020) built an inventory management and automatic warehousing virtual simulation experimental system through VR by using physical devices in the automatic sorting and intelligent stacking laboratory. This system realized automatic warehousing processes of "high integration, multi-links, and multi-categories" and virtual simulation of "multi-posts, multi-jobs, and multi-scene integrated" management process. It provided strong support to the professional talent training of logistics management [11]. Liu, X et al. (2019) explored applications of virtual simulation technology in warehousing process, warehouse facilities and equipment, supermarket purchase and spatial layout of warehouse. They also summarized the value of the application of virtual simulation technology in logistics teaching [12]. Gao, Y et al. (2016) used ExtendSim software to study the simulation teaching of warehousing courses, and analyzed the simulation effect combined with examples. They concluded that simulation teaching is conducive to deepening students' professional skills learning and the achievement of relevant teaching effects [13]. Shen, W et al. (2018) proposed the design idea of warehouse logistics experiment on the basis of the "grouping, process, and simulation" concept [14]. Guo, D et al. (2020) constructed a discrete event simulation model on the basis of queuing theory for the configuration of a storage robot in a smart warehouse [15]. Liu, H (2017) promoted the application of virtual simulation technology in the practical teaching of warehousing and distribution business in combination with the course link of "warehousing, in warehouse and out of warehouse" in the virtual simulation series. The application plays a role in updating theoretical teaching content, improving practical teaching, and improving students' learning interest [16].

Scholars have found that virtual simulation teaching has a good effect in logistics course teaching. However, the research on virtual simulation teaching focuses on the construction of simulation experiment platforms, the simulation of warehousing operation process, and the teaching value of virtual simulation. The extant research lacks the systematicness, timeliness, and exploration of virtual simulation teaching based on real, practical scenarios. Thus, this paper will reconstruct the teaching content according to the development trend of intelligent storage and the talent training orientation of higher vocational colleges, implement the content through modularization, propose the teaching mode, and design the teaching method that combines VR learning and real-world cases of enterprises. Through these enhancements, storage management theory and practical skills can be integrated in the teaching process.

3 Teaching reform for warehousing management curriculum based on VR technology

Warehousing management is the professional ability of warehouse managers; it involves broad knowledge structures and high requirements on technologies and skills. This curriculum not only teaches fundamental theories, but also practical skills. In practical teaching, due to hysteretic influences from excessive inputs for the construction of logistics training laboratories, theoretical teaching and practical training often cannot be implemented at the same time. Theoretical-integrated teaching cannot form organic integrity. Although students have mastered basic skills in warehousing activities through unit practical training modules, they have difficulty developing basic professional abilities that are essential as warehouse managers. Hence, the key in the teaching reform of the warehousing management curriculum shall combine theoretical knowledge teaching, practical skills training and practical work in intelligent warehouse, building VR warehousing working scenes using VR technology, developing the curriculum content, and designing the teaching mode on the basis of the professional position and task. The basic idea of the reform is introduced as follows:

3.1 Reconstruction of curriculum content

The teaching content of warehousing management curriculum is optimized dynamically by combining warehousing management business content in e-commerce enterprises, manufacturing enterprises, and logistics enterprises, talent training orientation of higher vocational colleges, as well as development trends of new technologies, new norms, and new philosophies in the warehousing management field. Moreover, the teaching content of warehousing management is reconstructed by focusing on entrance operation, inventory operation, and delivery operation of the intelligent warehouse. Three modules of warehouse layout plan, warehousing management, and warehouse inventory control were formed to meet the desired relevant knowledge and skills in the intelligent warehousing environment.

Module 1. Layout plan. A reasonable warehouse layout is the key to improve warehousing management efficiency. Warehouse layout includes the selection of logistics flow lines, setting of functional zones, configuration of facility equipment, and setting of transport paths. In the age of intelligent logistics, students are required to master professional knowledge for intelligent warehouse planning and design, be able to analyze the demands of intelligent warehousing, and make reasonable layout of different operation spaces. By combining intelligent equipment (e.g. intelligent AGV, working station, goods shelf, charging station, and other hardware equipment) in the field of intelligent logistics, students shall be able to configure supportive devices and reasonable layout for intelligent warehouse, complete transport path planning and simulation operation by using the planning system, and build high-efficiency warehousing environment for intelligent logistics.

Module 2. Operations management. The contents of warehousing operations mainly include goods entrance, loading and unloading, putting goods on shelves, goods storage, goods sorting, commodity package, delivery, information input, quality inspection, sales return, customer service, safety management, and equipment management. These contents are classified into the entrance operation, inventory operation, and delivery operation according to the operation processes of warehousing. Students are asked to master operation and process optimization in the intelligent warehousing management environment, including entrance operation, loading and unloading, storage operation, delivery operation.

Module 3. Inventory control. Inventory control is related with the stability and safety of supply chain operation as well as warehousing management cost control. The module requires students to master methods of inventory control, be able to predict customer demands accurately by using data tools and statistical methods, and realize reasonable inventory in warehouse by combining economic order model, quantitative regular ordering method, MRP inventory control method, and JIT inventory control method.

For example, Harris proposed the economic order batch model in 1913 [17]:

$$TC(Q) = PR + \frac{CR}{Q} + \frac{PFQ}{2}$$

$$\frac{dTC(Q)}{dQ} = \frac{d}{dQ}\left(PR + \frac{CR}{Q} + \frac{PFQ}{2} \right) = 0$$

$$\frac{PF}{2} + \frac{CR}{Q^2} = 0$$

$$\frac{PF}{2} = \frac{CR}{Q^2}$$

$$Q^2 = \frac{2CR}{PF}$$

$$Q^* = \sqrt{\frac{2CR}{PF}} = \sqrt{\frac{2CR}{H}}$$

Q* – economic order batches
R – annual commodity demands
C – order cost per time
P – unit price of commodities
F – percentage of annual storage cost per unit commodity in the total commodity value
H – annual storage cost per unit commodity

In the warehouse inventory control, enterprises can regulate inventories and make reasonable changes in warehouse inventory by using order quantity with the lowest total inventory cost. In teaching, the order quantity is calculated by the economic order quantity model by combining the operation data of enterprises. Purchase operations are implemented next using a simulation software, and cost analysis is carried out by operating for a period. These exercises train students' abilities in data analysis and inventory control in the intelligent warehousing environment.

3.2 Build-Task-Exercise-Evaluation (BTEE) teaching mode design

BTEE refers to building virtual warehouse working scene (build), designing working tasks based on real cases (task), task-based progressive exercise (exercise), and systematic real-time tracking evaluation (evaluation). Based on the BTEE mode and supported by VR technology and computer technology, BTEE teaching mode builds a new VR warehousing management learning space by using real-world cases from enterprise warehouses, breaking the traditional task-driven teaching mode, and bringing students into a virtual working scene to conduct task training. Students complete tasks of warehouse managers through immersive experiences, and their performance in tasks can be evaluated systematically in real-time. This approach stimulates and guides students to learn various knowledge points and skill points in warehousing management. In this way, students' training in warehousing management skills is strengthened. Figure 1 shows the BTEE teaching process.

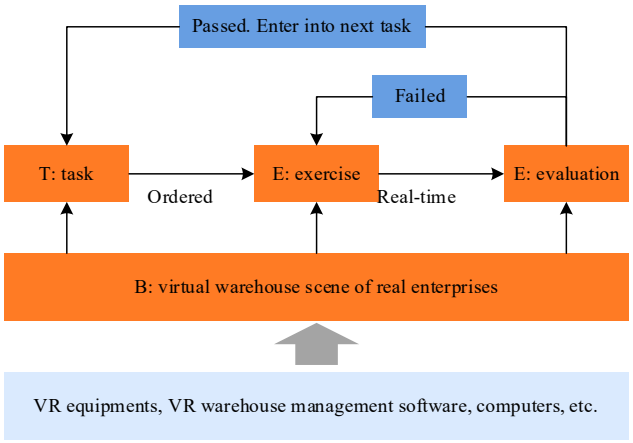

Fig. 1. BTEE teaching mode

3.3 VR-based teaching method design

To increase the connection between teaching of warehousing management and warehousing management of real enterprises and to increase the learning enthusiasm of students, virtual enterprise warehouse was built using VR technology and computer technology. Real enterprise warehouse operation cases were introduced through school–enterprise cooperation. Moreover, the virtual enterprise warehouse and real enterprise warehouse operation cases were integrated by task-oriented teaching mode. Thus, the teaching design in each task in every module was formulated from "input of real tasks and determine task" → "teaching task-associated knowledge and skill points" → "demonstration of cases" or "discussion of problem solutions" → "implementing task train with VR software" → "learning and training evaluation and summarization." Figure 2 shows the process as below:

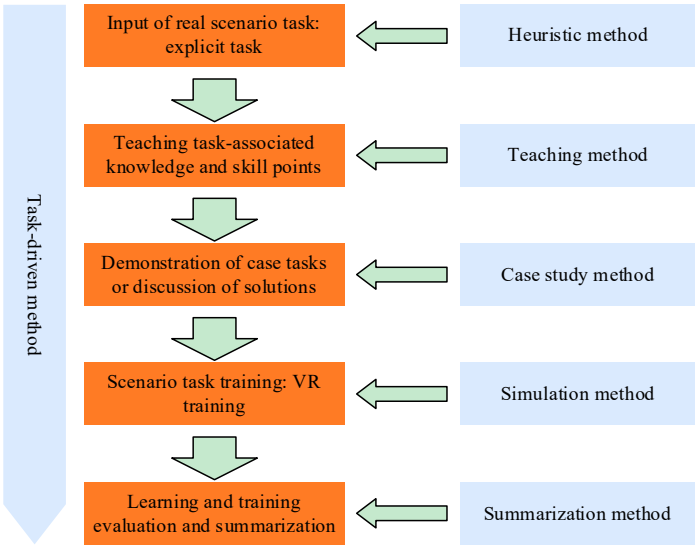

Fig. 2. Design idea of teaching method

4 Teaching case and teaching effect

4.1 Teaching case

The VR warehouse logistics training system was used as a platform, and a virtual warehouse scene was built on the basis of the warehouse of an enterprise to teach "warehouse layout design" in the module "warehouse layout planning." Warehouse layout design mainly addresses the dynamic linear layout of warehouse and setting of functional zones.

Dynamic linear layout selection. the logistics line refers to the moving tracks of goods in the warehouse from entrance to exit. The dynamic linear design emphasizes on man–goods separation and meets specific functions in the process of warehouse operations while assuring smooth, high-efficiency, and convenient logistics operations. Students have to distinguish dynamic linear types, choose the appropriate dynamic linear layout design according to warehouse type, and optimize the layout continuously. Common dynamic linear layouts of warehouses include U-shaped layout, I-shaped layout, L-shaped layout, and S-shaped layout (Figure 3).

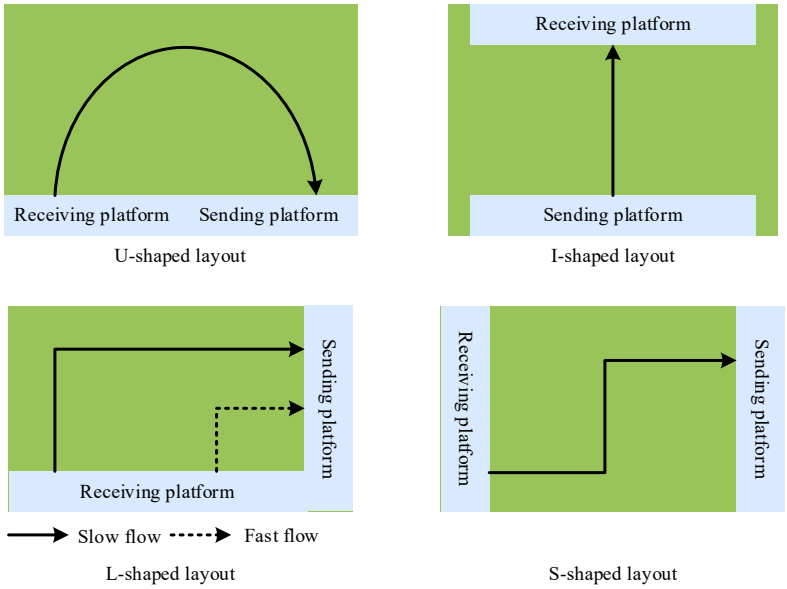

Fig. 3. Dynamic linear layouts

Layout analysis of functional zones. A warehouse is divided into different functional zones, such as receiving platform, sending platform, goods sorting zones at the entrance and exit, warehousing district, and sorting zone (Table 1). The warehouse plane is divided into various operation zones according to laws and standards. In addition, positions and areas of each zone are determined according to specific situations.

Table 1. Analysis of the characteristics of functional zones in a warehouse

Functional zone / Type	Receiving platform	Goods sorting zone at the entrance	Warehousing district	Sorting zone	Goods sorting zone at the exit	Sending platform
E-commerce	In and out at the same time	Many categories Many individual items	Requirements on flexibility	Space demands are high and complicated.	Many categories Many disassembly items	In and out at the same time
Freezer	Closed appropriately	Small sized Freezing is necessary.	Large Zoning is needed. Automatic	As small as possible or N/A	Small Temperature control is needed.	Closed appropriately
Fast moving consumer goods	Great fluctuation of purchase quantity	High requirements on buffer capacity	Quick response	Moderate. Many bulk items	High requirements on buffer capacity	Great fluctuation of delivery quantity
Medical	Moderate Emergency degree shall be considered.	Moderate Medicines requiring low-temperature shall be considered.	Large space Temperature and humidity are stable.	Large Many categories	Moderate Medicines requiring low-temperature shall be considered.	Moderate Emergency degree shall be considered.

Warehouse layout design scheme and simulation. The warehouse layout scheme is designed on the basis of an e-commerce warehouse of an enterprise, and simulation training was implemented (Table 2). A U-shaped layout is designed according to the provided general information, cargo information, shelf information, equipment information, and inventory information (Figure 4).

Table 2. Information from an e-commerce warehouse of an enterprise

Information type	Information content
General	Floor: bearing capacity of 4,000 kg/m^2 Roof: plane, safety distance = 0.5 m. Calculating the lowest roof height according to following specific information is necessary. Safety: maximum permissible driving speed of transporting equipment = 5 km/h
Goods	Name of goods: Thomas the Train toys Type of goods: bulk Tray information: dimensions = 1,200 mm × 1,000 mm × 160 mm, weight = 20 kg, stacking height limit (excluding tray height) = 1,000 mm Goods information: dimension = 203 mm × 153 mm × 160 mm, limits in number of stacking layers = 6, weight per box = 10 kg. Each box has 10 items. Principle of arranging the goods: try to occupy the tray space and shelf space as much as possible. Characteristics of transporting the goods: frequent, easy impact on floor, no corrosion
Shelf	Three shelves are optional. Please choose and elaborate reasons. Shelf 1: unit size = H 6,000 mm × W 2,700 mm × D 1,000 mm, column width = 100 mm, beam height = 100 mm, bearing capacity of unit shelf = 10 t Shelf 2: unit size = H 6,000 mm × W 2,640 × D 1,000 mm, column width = 80 mm, beam height = 80 mm, bearing capacity of unit shelf = 6 t Shelf 3: unit size = H 8,500 mm × W 2,700 mm × D 1,000 mm, column width = 100 mm, beam height = 100 mm, bearing capacity of unit shelf = 12t

Equipment	Please choose from the following forklifts and pallet trucks, and elaborate reasons. Forklift 1: balanced heavy forklift (electric) tonnage: 1.5 t Speed: 0–20 km/h Lifting height: 3 m (single-level gantry) Forklift 2: balanced heavy forklift (electric) tonnage: 2 t Speed: 0–15 km/h Lifting height: 9 m (3-level gantry) Pallet truck 1: tonnage: 1 t Box handling capacity: 100 boxes Plastic logistics box handling capacity: 100 boxes
Inventory	References for setting the upper and lower limits of storage space and inventory on electronic tag: Maximum order quantity per order: 50 pcs. Maximum capacity per electronic screening shelf: 500 pcs. References for setting the upper and lower inventory limits of flat warehouse (sorting zone): The flat warehouse in the sorting zone is for bulk delivery or supplementing goods for electronic screening shelves (unit: box). Flat warehouse size in the sorting zone: 2 m × 2.5 m. Only single-layer stacking of trays is allowed.

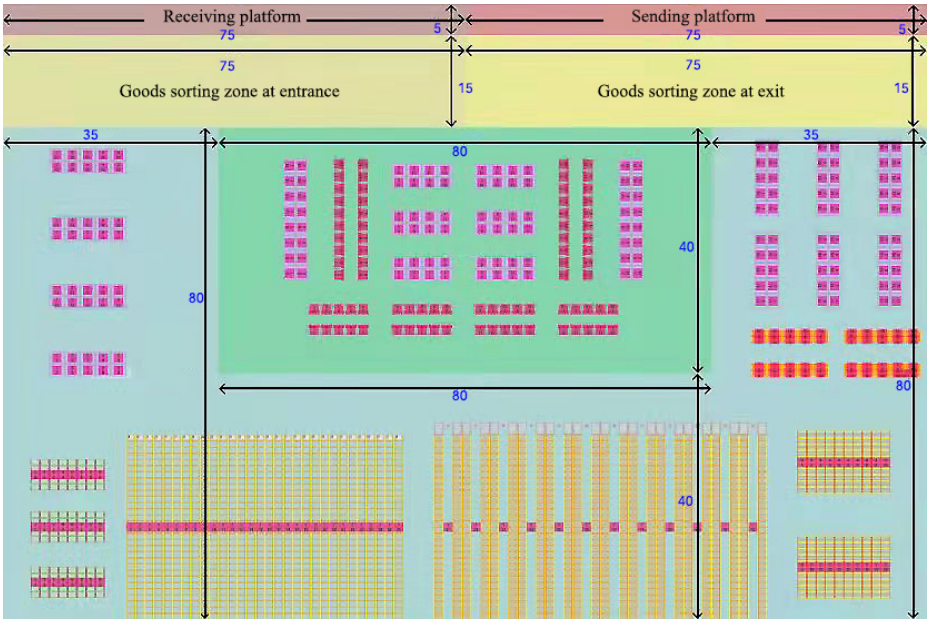

Fig. 4. Simulation results of a U-shaped e-commerce warehouse

4.2 Teaching effect

Our school has been exploring the teaching of warehousing management in the logistics management major by using VR simulation technology. The feedback of 215 students majored in logistics management who were admitted in 2019 and 2020 in the Warehousing Management course were obtained through an online questionnaire

through the Wenjuanxing App. A total of 212 responses were received, thus reaching a questionnaire recovery rate of 98.6%. Among them, 198 reported valid answers; thus, the effective questionnaire recovery rate reached 93.4%. The responses reflect the learning situation of students and the teaching effect of the proposed reform. The teaching mode and method of the curriculum and vocational skills were carried out according to the questionnaire contents, statistics, and analyses on the learning state of students. Figure 5 shows the results.

The survey results revealed that all students could keep up with teaching schedule of BTEE and adapt to the VR simulation teaching environment. A total of 163 respondents could integrate into the BTEE teaching schedule easily, and another 35 could integrate into BTEE teaching. All students could integrate into the virtual scenario after adapting to the roles and then finish tasks successfully.

In view of the BTEE teaching reform, all students liked the theoretical teaching–practical training integrated teaching mode, which taught theoretical knowledge and provided practical training at the same time. Some respondents (85%) believed that VR simulation teaching of warehousing management realized characteristics of warehousing management skill practicing, and the adopted teaching method conformed to learning characteristics of students in higher vocational colleges. The majority of respondents (95%) believed that BTEE teaching reflected the action-driven teaching method and focused on "teaching–learning–practicing integration," thus improving their efficiency in mastering knowledge and skills. With respect to the professional skill experiences of students, 90% of respondents reported that BTEE teaching for Warehousing Management was very helpful in their career experiences. All students believed that VR practicing space provided by BTEE teaching was more vivid and intuitive than the traditional teaching method. Moreover, it saves time and guarantees their security compared with actual visits to real warehouses.

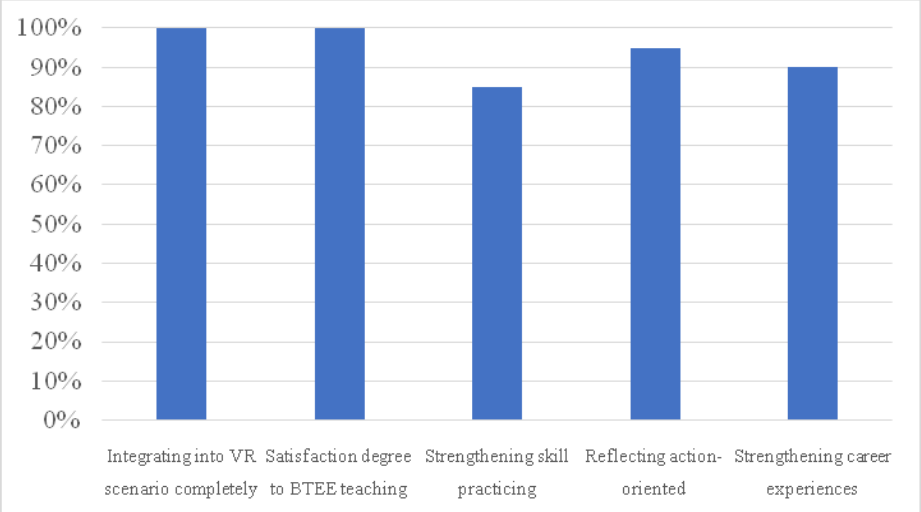

Fig. 5. Results of the survey among students

5 Conclusions

Based on applications of VR simulation technology in teaching, this study explores BTEE education mode for Warehousing Management to cope with intelligent warehousing management. Moreover, the BTEE education mode optimizes curriculum content, creates immersive VR warehousing management training environments, and matches content updating with the innovative task-oriented teaching mode. According to a survey on students who were admitted to Logistics Management in 2019 and 2020, the task-driven teaching mode based on VR technology improves the skill training efficiency and quality of students effectively. Major conclusions could be drawn:

1. Applications of VR simulation technology extend the single scenario mode in traditional logistics training laboratory. Limited by available equipment, the traditional logistics training laboratory is restricted in training of a link and an operation. By contrast, VR logistics software can build warehousing environments of different enterprises and can use warehousing equipment that cannot be used otherwise in teaching activities for different reasons. This advantage not only improves students' cognition of different warehouse layouts and different warehousing processes, but also improves their thinking ability in links-integrated operation of warehouses.
2. The use of VR simulation technology develops advantages of task-oriented teaching mode. The curriculum uses data from real enterprise warehousing projects, which are then deconstructed into different tasks according to three modules of the curriculum. All tasks are trained in the built virtual warehouse platform. This approach integrates theoretical teaching and practical training effectively and helps improve students' intelligent warehousing management abilities by applying knowledge to practical scenarios.
3. The curriculum content reform is in line with the development of the intelligent logistics industry. The direction and objective for students to learn curriculum in the intelligent logistics environment are determined. Meanwhile, curriculum teaching is promoted through modularization. Guided by different modules and VR virtual logistics software, different apps are introduced, such as data analysis software and warehousing management system. Attention shall be paid to improve the comprehensive warehousing management ability of students.

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