Industrial Robot Teaching Reform and Practice based on Flipped Classroom and Robot-Studio

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ABSTRACT

This article, based on the actual teaching of the basic course, analyzes the significance and role of Robot-Studio virtual simulation software in higher vocational industrial robotics education. The most challenging aspect of industrial robot teaching is operation. Given the limitations and exclusivity of actual resources, it is proposed to utilize a virtual simulation platform, which can provide a practice environment close to reality and expand the applications of industrial robots. An "Industrial Robot Trajectory and Process Simulation Experiment Project Based on Intelligent Manufacturing" was developed and applied to experimental teaching in courses such as Modern Robotics Technology, Manufacturing Process Planning, and FMS. This approach broadened and deepened the content of experimental teaching, extended the time and space of experiments, and greatly improved the quality and level of experimental teaching. By applying flipped classroom and virtual simulation, the industrial robotics courses have been designed and practiced, enabling students to achieve corresponding knowledge, understanding and hands-on operation skills.
Keywords: flipped classroom, industrial robotics, operation skill, simulation experiment, virtual simulation

INTRODUCTION

According to the strategic development requirements of "Made in China 2035," the current period is a critical stage for the transformation of China's manufacturing industry to a high-level development model. The strategy points out that industrial robots, as an important focus in the field of intelligent equipment, bear the key responsibility of advancing China from a manufacturing power to a manufacturing strong nation. Industrial robots, due to their high level of intelligence, are widely used in manufacturing product production lines and can be seen in fields such as handling and stacking, automotive parts processing, metal cutting, metal welding, and flexible polishing [1]. By replacing humans in harsh working environments and ensuring work quality, industrial robots maximize production efficiency and play an important role in reducing labor intensity and saving production costs.

The development of the intelligent manufacturing industry, represented by industrial robots, has led to a market demand for technically skilled talent. In response to national policies, adapting to industry development needs, and serving social and economic construction, numerous domestic universities have established programs in industrial robot technology applications [2]. As an emerging discipline in higher education, the course construction for this program is still under exploration. "Fundamentals of Industrial Robot Technology" is the core professional course of the industrial robot technology application program in universities and serves as the theoretical foundation for various skill training courses in this program [3]. However, currently, the course construction cannot meet the requirements for cultivating technically skilled talent. Some universities face problems such as overlapping knowledge points, an imbalance between theoretical knowledge and practical skills, and a disconnect from actual work content, highlighting an urgent need for curriculum reform research.

Robot-Studio is a virtual simulation software for ABB robots, integrating functions such as workstation creation, program compilation, simulation debugging, and secondary development, capable of simulating real working environments [4]. This software includes a library of ABB industrial robots from any series, allowing the creation of different robot tasks. It features virtual controllers and teach pendants that are largely similar to those of real ABB industrial robots. Therefore, when conducting virtual simulation experiments with this software, users can experience a sensation similar to being on a real robot operation site. Virtual simulation experiments replace traditional physical demonstration experiments, which on one hand solves issues such as insufficient experimental funds, time constraints, and space limitations; and on the other hand, reduces maintenance costs and minimizes the potential consequences of student disoperation. In virtual simulation experiments, students have ample time to repeatedly practice and correct errors, allowing them to conduct both verification experiments and innovative experiments. Students can choose different components and robot models to design various robot operation scenarios, breaking away from traditional fixed thinking, applying theory to practice, and greatly enhancing learning interest, and "interest" is the best teacher. Additionally, virtual simulation can promote the development of "educational equity," as every student can have access to the same experimental equipment. No student will miss out on understanding the experiment because they are too far away to hear or see the teacher's demonstration, nor will they be limited by a shortage of equipment or crowding.

The term 'flipped classroom' is translated from the English 'flipped classroom' and can also be rendered as 'inverted classroom.' Its basic concept is to readjust the allocation of time inside and outside the classroom, allowing students to first acquire foundational knowledge independently outside of class, so that more valuable classroom time can be reserved for teacher-student interaction and deep learning, thereby achieving better teaching outcomes. Benefiting from the rapid development of information technology, the internet and virtual simulation teaching resources have become increasingly abundant and sophisticated, providing favorable conditions for teachers to implement flipped classrooms. By leveraging online and offline platforms, the concept of flipped classrooms is introduced into practical teaching of industrial robots, dividing the entire teaching process into three stages: pre-class self-study exercises, in-class consolidation and hands-on practice, and post-class extension and improvement.

In higher education industrial robot operation teaching, there are some issues such as limited teaching resources, insufficient opportunities for students to practice equipment operation, and a high rate of equipment damage. The industrial robot virtual simulation technology platform creatively provides specific scenarios fully supported by virtual 3D models and computer technology, which can be used for student learning, teacher research, school competitions, and school-enterprise cooperation. Teachers can use simulation learning to present the complex and obscure theoretical knowledge and core points of industrial robots; students can establish a verification relationship between theory and operation through simulation applications, realize concrete explanations, contextualized operations, and personalized learning. While learning new skills, students also accumulate experience in industrial robot operation programming. The industrial robot virtual simulation courses face some practical issues: there are few schools offering them, the courses have been established for a short time, and the teaching effect is not satisfactory. The main purpose of offering these courses is to address equipment shortages and enhance students' advantages in skills competitions. The "Offline Programming and Simulation of Industrial Robots" course has long been a core course in higher vocational and undergraduate industrial robot programs. Developing this course in secondary vocational schools is beneficial for laying a solid foundation, establishing an advantage, and helping students better adapt to the learning intensity after entering higher vocational education. Occupational student skills competitions are upgrading every year, and the events increasingly require students to have the ability to use simulation software. Employers also report that some students have weak theoretical knowledge, insufficient operational skills, and limited competitive advantages in job positions. These realities indirectly reflect that developing a virtual simulation technology application course for industrial robots in higher education aligns with the practical needs of professional development in secondary vocational schools and is somewhat helpful in establishing professional advantages.

Developing the course "Fundamentals of Industrial Robotics Technology" is more challenging compared to other practical skill-based courses [5]. The reason lies in the fact that, as a foundational integrated theory-practice course for the Industrial Robotics Technology application major, it contains a substantial amount of theoretical knowledge with scattered key points. This makes it difficult to align with specific job positions to conduct task and professional competency analyses, which could otherwise provide a foundation for the subsequent construction of the knowledge system. Therefore, this study focuses primarily on the course knowledge points themselves. Based on the presentation and organization of these knowledge points, it actively promotes the integration of course development content with specific enterprise training tasks to concretize the course knowledge. This effectively facilitates the extraction of integrated theory-practice teaching content in the course, with an emphasis on analyzing work scenarios during task execution. This allows students to understand both the fundamental principles and conceptual knowledge through hands-on training, enhancing the systematic structure of knowledge and the interrelation of knowledge points. It provides a reference case for higher education researchers developing foundational technical courses, and improved course development approach can also offer insights for further exploration of advanced course development theories in the future.

THEORETICAL FRAMEWORK

Currently, exploring curriculum development models that fit the national context has become an important theme and trend in the development of vocational education in various countries. Vocational education developed countries have accumulated a lot of experiences that can be learned from and referenced. Some of the relatively mature foreign curriculum development models include the competency-based curriculum development model, the MES curriculum development model, and the German 'dual system' curriculum development model.

The competency-based curriculum development model, also known as the CBE curriculum development model, is a prevalent approach in vocational education curriculum development in North American countries [6]. The CBE curriculum development model emphasizes student-centered learning, with the cultivation of professional competencies as the goal. It establishes a curriculum development process that ranges from job analysis to instructional task analysis. Different teaching modules are designed according to the learning progress, and the knowledge points derived from specific job tasks are implemented with the principle of being "practical and sufficient." The CBE curriculum model focuses on the comprehensive development of students' abilities, including knowledge (theoretical knowledge related to job competencies), attitudes (work attitude, motivation, and other emotional factors), practical experience (specific operational and managerial skills), and feedback (the ability to self-assess and improve).

The MES course development model is a development approach presented in the form of vocational training. It is based on systems theory and cybernetics as the theoretical foundation for its course development path, viewing the process of vocational and technical training as a complete dynamic system, with vocational training occupying an important position in the final curriculum system.

The German dual system is a curriculum model based on school-enterprise cooperation [7]. This model has a supporting development framework, and the specific development path can be understood in three steps: the arrangement of curriculum standards, the structuring of the curriculum's logical system, and the actual implementation of the curriculum.

By drawing on the curriculum development models of vocational education from abroad and combining them with the actual development needs of local vocational education, China has formed the 'broad foundation, flexible modules' curriculum development model, the 'work-process-oriented' curriculum development model, and the 'project-based' curriculum development model [8].

Vocational education curriculum research expert Jiang Dayuan, drawing on the experience of vocational education curriculum development in Germany, proposed a 'work process-oriented' curriculum development model [9]. The specific implementation of this model involves breaking down the logical system of traditional disciplines and then reconstructing a development process that reflects the action-oriented nature of vocational education. Its focus lies in analyzing work processes in contextualized situations, and through instructional treatment and transition, transforming curriculum content into a knowledge system that represents the work process. Moreover, the teaching modules are interconnected and progressively challenging.

"Project-based curriculum" is a curriculum development model advocated by vocational education experts such as Xu Guoqing and Shi Weiping [10]. The content of a "project-based curriculum" is determined based on enterprise job clusters. Specific work tasks are identified through the analysis of these job clusters and are used as the foundation for the development of "project" courses. Its project carriers are relatively independent activity modules, such as a particular product or service.

To this day, task-driven curriculum development has become a major trend in international education curriculum reform. Many countries have begun to widely apply such curricula at different educational stages. A representative example is the United States' "Second Step" program, which focuses on bullying prevention and aims to improve students' emotional management during adolescence [11]. The curriculum is designed in task-driven, spiraling chapters according to students' different developmental stages and cognitive levels.

Amberg University of Applied Sciences in Germany, based on the curriculum characteristics of the computer engineering program, adopts a task-driven introduction method centered on real challenges that may arise in future computer engineering work [12]. The curriculum is divided into theoretical learning modules and skill training modules, emphasizing hands-on engineering practice to guide theoretical learning, establishing an educational model of 'learning through application' and 'advancing learning through use.' In the UK, architecture education courses in task-implementation scenarios, with the joint support of teachers and students, cultivate the creative design abilities of professional architects within real architectural contexts [13]. Tokyo University of the Arts, in collaboration with community education, expands courses through community activity-based task driving, leading students to conduct art creation educational activities within the community, breaking down barriers between teaching domains and strengthening connections between areas of professional knowledge [14]. The course development at the Danish University College of Sports Education focuses on general education, with curriculum principles emphasizing experiential and interest-based learning. In a task-driven context, teachers employ engaging and inquiry-based teaching methods, and course assessment approaches are relatively diverse.

Among them, Zhen Jiujun addressed the shortage of textbooks and the low adaptability of students to practical training in the CNC technology programs at some vocational institutions by undertaking a curriculum development and reform effort for the CNC course 'CNC Machine Tool Fault Diagnosis and Maintenance,' organizing content around five learning scenarios: CNC machine tool management, mechanical component maintenance, and control system assembly and debugging [15]. Cai Jiancong developed the secondary vocational program course 'Installation and Commissioning of Intelligent Control Devices' based on task-driven logic using typical work tasks, highlighting a teaching evaluation process that thoroughly integrates professional qualifications closely related to students' future careers and focuses on assessing students' problem analysis and solving abilities through project-based learning [16]. In higher vocational computer course reform, Yan Lixin designed six major modules based on practical training tasks, including stage task modules, comprehensive task modules, and competition task modules, subdivided tasks across these modules, and conducted secondary development of task-driven course resources, providing guidance for the development of hands-on computer courses [17]. Tang Yafeng, in developing intelligent automobile training projects for secondary vocational schools, analyzed the core components of intelligent vehicles and divided the comprehensive training content for smart connected vehicles into four practical training tasks: intelligent sensors, computing platforms, smart cabins, and drive-by-wire chassis, with chapter design based on the vehicle entities, ensuring coherent and logically connected content [18]. Yan Hao and colleagues, incorporating the actual working environment and requirements of chemical production, analyzed typical chemical production tasks, using the operational procedures of relevant equipment as a reference and customizing the core skills training in the teaching process according to the needs of chemical production enterprises, effectively recreating workplace scenarios from 'environment' to 'methods' to 'process'[19].

Abroad, while improving the level of product research and development of robots in their application fields, there is also great emphasis on the construction of robot education. As one category of robots, industrial robots can benefit from referencing the development of robot education abroad to provide experience for curriculum development. In the United States, robot education courses are mainly offered in four forms: technical foundation courses, comprehensive practical courses, summer camp activities, and robot teaching auxiliary courses. The teaching themes focus primarily on deep learning, process guidance, and career experience, among which the most representative are the series of courses such as "Introduction to Robotics" developed by MIT [20]. The core content of these courses is to have students build robot models, during which they gain a clear conceptual understanding of the basic components of robots, thus testing their knowledge level and operational skills. In Japan, robot education is designed and implemented according to the different stages and needs of students. For elementary school students, robot education mainly aims to cultivate interest and creativity according to their psychological and cognitive development level. At junior and senior high schools, the teaching method primarily involves robot competitions, allowing students to enhance their abilities through hands-on practice. At university level, the focus is on studying robot mechanics and product development methods.

The model of vocational education in Europe is characterized by school-enterprise cooperation. In the curriculum system of the robotics major, the participation of manufacturers of robotics teaching products is relatively high. Scholar Schilling, R pointed out that during teaching and research, we can provide feedback and production guidance on manufacturers' products so that their products can meet the basic requirements of educational applications as much as possible. In addition, leading industrial robot companies have mostly developed their own training course systems. For example, Swedish ABB Robotics, Japanese FANUC Robotics, and German KUKA Robotics have developed a set of teaching courses for using their company's robot products along with supporting equipment resources. They have also developed teaching software for virtual simulation of industrial robot workstations to realize an integrated teaching platform for industrial robot courses. Western countries such as Germany and the UK have introduced relevant robotics education policies. For instance, the German Federal Ministry of Education and Research, in the "Information and Communication Technology 2020—Research for Innovation" project, applies developed robotics information teaching kits in classrooms to improve teachers' efficiency in teaching robotics, helping students understand robotic technology, and stimulating students' cognitive understanding of knowledge such as robot information circuits and the cultivation of logical control thinking [21].

Research on project-based course development for industrial robots mainly includes: Tan Panlong applied the CBE CDIO concept to industrial robot application courses by gradually increasing difficulty and organized them into project-based courses. Following the product design stages of 'conceive—design—implement—operate' and guided by engineering project design, he designed three major project modules: basic, specialized, and comprehensive, which further derived thirteen smaller practical training modules. Liu Wenjie conducted research targeting robot system integration companies, extracting five typical enterprise cases: assembly line handling, assembly line palletizing, automotive glass glue application, circular segment cutting, and PCB board assembly, to develop a project-based course on 'Industrial Robot Operation and Programming.' Qi Xiaoling, based on the technical requirements of different industrial robot job positions, divided the course content of 'Industrial Robot Operation and Programming' into three major modules: core basic exercises, on-machine virtual simulation, and comprehensive practical training tasks. Jia Weiping and others carried out a task-driven industrial robot experiment design and development. Based on the analysis of the mechanical structure and control system of industrial robots, they designed practical training projects, with robot handling for loading and unloading and innovative design content as the final teaching projects.

Some issues partially deviate from enterprise needs and the rules of career development. Chen Yang applied the theory of systematic work processes to develop the secondary vocational course 'Industrial Robot Maintenance and Testing,' analyzing four learning scenarios specifically for robot maintenance and testing: inspection and recording, adjustment and maintenance, component repair and replacement, and complete machine assembly and disassembly. He combined the basic work process of 'information, planning, decision-making, implementation, testing, and evaluation' to carry out the course teaching design and propose evaluation strategies. Xiong Feng used a work process-based systematic course development method to present the secondary vocational course 'Industrial Robot Vision Applications' with basic visual functions as the carrier, designing four learning scenarios with progressively increasing difficulty. In addition, he created integrated student learning work sheets and designed diversified, process-oriented evaluation forms. Tian Yong and others applied the systematic work process method to redesign the 'Industrial Robot System Integration' course structure, with work scenario designs based on real industrial robot production environments and system equipment setup training, sequencing the course content into the entire process of robot workstation programming and debugging.

Considering the basic characteristics of the 'Fundamentals of Industrial Robot Technology' course in vocational secondary education, a curriculum structured in a 'task-driven' format holds significant reference value. Organizing course chapters according to a 'task-driven' approach is transferable. In classroom teaching activities, presenting learning content in the form of chapter-based tasks allows these tasks to serve as the fundamental learning objects for students, which can be applied to other similar vocational contexts in the future. This approach reflects the 'vocational nature' inherent in vocational education courses and effectively addresses the current issues in the 'Fundamentals of Industrial Robot Technology' course at vocational secondary schools, where knowledge points lack logical coherence and fail to connect with practical production.

METHOD

The literature research method mainly refers to the collection, identification, and organization of literature, and through the study of literature, forming a scientific understanding of facts. This study analyzes the current advanced concepts in vocational education curriculum development and reviews the mainstream domestic and international vocational education curriculum development models, providing theoretical and methodological support for the curriculum development process of this research. At the same time, various databases were searched using keywords such as 'curriculum development' and 'secondary vocational industrial robot courses' to summarize and integrate practical research results on industrial robot curriculum development. By referencing current research achievements and specific development paths, and through extensive literature collection, analysis, organization, and comparison, the main direction and specific content of this study are determined.

The questionnaire survey method refers to a quantitative measurement approach that involves selecting survey subjects based on the content of the survey, designing, distributing, and collecting questionnaires for analysis. In the early stages of course development, this study conducted a questionnaire survey among instructors and students of the 'Fundamentals of Industrial Robotics' course in higher education institutions to investigate the current status of the course and identify issues that need to be addressed. During the implementation evaluation stage after the course development, for the target participants of the course, a questionnaire survey was conducted to assess the effectiveness of the 'Fundamentals of Industrial Robotics' course development in terms of teaching satisfaction, achievement of course objectives, and acceptance of the teaching.

In the field of educational research, the empirical research method refers to a method in which educational researchers carry out teaching practices and collect relevant materials or experiential data from the implementation process to verify proposed teaching theories or test teaching effectiveness. This study conducted empirical research on curriculum development at Zhejiang Institute of Mechanical and Electrical Vocational College, using Class A of the 2024 Industrial Robot Technology Application major as the target for teaching practice. A theoretical-practical integrated classroom teaching model was constructed, and a three-month classroom teaching practice was carried out. Finally, the implementation effect of the "Fundamentals of Industrial Robot Technology" course development was tested through a course evaluation system based on the CSE course evaluation model.

This article attempts to combine the flipped classroom and task-driven teaching methods, applying them to the course 'On-Site Programming and Debugging of Industrial Robots,' and divides the teaching process into the following five main stages.

1. Set up guiding prompts to help students acquire theoretical knowledge

For the theoretical knowledge required for course practice projects, text-based guided prompts are set up, which include several questions. On one hand, this stimulates students' interest in learning, and on the other hand, it guides students to explore relevant knowledge points before class. Taking the project 'Establishing ABB Industrial Robot Tool Data' as an example, the guided prompt can include the following questions: What types of tools do industrial robots have? What coordinate systems do industrial robots have? What is the tool coordinate system of an industrial robot? Why establish a tool coordinate system? Besides the tool coordinate system, what other data does tool data include? How to establish tool data? How can you verify whether the tool coordinate system you established is valid? The guided prompt must be assigned before class and students are required to complete it before the class. This is a basic requirement of the flipped classroom, where students should complete the learning of the theoretical knowledge needed for the class before the class begins.

2. Assign project tasks to strengthen students' goal orientation

While assigning the guiding text, classroom project tasks should also be arranged. This follows the action-oriented teaching method, allowing students to understand the practical use of theoretical knowledge while exploring it through the guiding text, rather than learning for the sake of learning. Providing them with a clear project objective can further enhance their interest in learning and strengthen their initiative. Taking the project 'Establishing ABB Industrial Robot Tool Data' as an example, in addition to the guiding text, a clear project objective document should be given to students before class, such as 'Install a grinding tool on the IRB1200 industrial robot and establish the tool coordinate system,' or 'Install a welding tool on the ABB industrial robot and set up the coordinate system.' Projects should focus on core knowledge points, allowing students to complete the project using the knowledge gained from the guiding text, thereby enhancing their mastery of both knowledge and skills.

3. Guide students to develop a work plan

Proper planning leads to success, while lack of planning leads to failure. Before students formally start hands-on practice in the classroom, teachers should complete the following two tasks:(1) Check students' pre-class theoretical knowledge through random sampling. On one hand, this can supervise and encourage students to effectively complete the study of the guiding materials before class; on the other hand, it can identify and slightly analyze any difficulties students encounter in their learning. (2) Organize students into groups and guide each group in creating a work plan for the project they need to implement. The work plan can include the composition of members, division of responsibilities, and stages and content of the project work. Teachers should provide reasonable comments and corrections on any inappropriate parts of the work plans prepared by the groups. Through this activity, students can develop teamwork skills for collaborative work and cultivate good habits in planning and organizing tasks.

4. Organize students to carry out project tasks

The implementation of project tasks is the core process of this teaching method. In this part, the teacher's role is still that of a guide, while students remain the focus of the class, which aligns with the educational concepts of both flipped classroom and action-oriented teaching methods. In this stage, students both divide tasks and collaborate, gradually completing practical projects based on pre-class theoretical knowledge and work plans. For example, in the project 'Establishing ABB Industrial Robot Tool Data,' students need to operate the robot through the teach pendant to reach the appropriate position, replace the robot's tool as required, establish the tool coordinate system through the teach pendant, and finally verify whether the tool coordinate system is correct. During these operations, students repeatedly validate theoretical knowledge through practice, ensuring a deeper understanding of the acquired skills and knowledge. The teacher provides minimal guidance during this process, intervening only to prevent serious errors or unsafe situations, without excessively interfering with the students' practical activities.

5. Project Evaluation and Project Summary

Teachers establish a comprehensive evaluation system to better reflect and recognize the work done by students, enhancing their learning information and interest. After the project is completed, students are organized to evaluate their own work, group members evaluate each other, groups evaluate each other, and finally, teachers also give a certain evaluation of each group's work. Students' scores should take all these evaluations into account. Finally, teachers summarize the entire project implementation process, affirm the well-completed tasks, correct any mistakes, review theoretical knowledge, reanalyze difficult points, and strengthen students' understanding of key concepts.

FINDINGS AND DISCUSSION

In the teaching of various courses in the industrial robot major, such as the basics of industrial robots and on-site programming of industrial robots, the virtual simulation application of industrial robots will be involved. Virtual simulation technology plays a role in connecting various knowledge points in the course. Robot-Studio builds workstations, performs offline programming, program debugging, and motion simulation for robots and peripheral equipment. Finally, the debugged programs can be applied to real training teaching or production practice. The specific application is shown in the table below.

Table 1. Application of Robot-Studio in Professional Courses

Level	Course	Application
Basics	Industrial Robot Basics	Robot Basic Cognitive Operation
Advanced	Industrial Robot On-site Programming	Offline Programming
Advanced	Industrial Robot Workstation Installation and Debugging	Workstation Virtual Simulation
Expansion	CAD/CAM Software Application	Tool Modeling
Expansion	Flexible Manufacturing and Production Line	Smart Components

The core professional competency requirements of the industrial robot major are to be able to maintain and service industrial robot application system equipment, to eliminate simple electrical and mechanical faults; to compile and adjust industrial robot control programs according to the job requirements of the automated production line; to install and debug industrial robots and application systems according to the requirements of industrial robot application solutions. The professional course structure includes modules such as basic robot operations, offline programming, and system design, including RobotStudio virtual simulation technology, which can be well connected with corporate job capabilities, combined with project-based teaching design and immersive teaching methods to improve students' professional core skills and professional quality.

Manual manipulation of industrial robots in practice, in the teaching of the basic course of industrial robots, the manual operation of robots is one the important learning content connects the two major knowledge modules from the basic theoretical knowledge of robots to robot programming. Since students have not really touched the robot and still have a certain "awe" of the robot, using Robot-Studio to virtually simulate the manual operation of the robot can play a good teaching effect. In the author's actual teaching, this part of the content is dedicated to 4 class hours for virtual simulation training. The three motion modes manually operated by the robot include single-axis motion mode, linear motion mode, and repositioning motion mode. Students can observe the 1-6 axis single-axis motion state of the robot in real time in the software, the linear motion trajectory in the X, Y, and Z directions in the linear operation mode and the TCP point in the repositioning mode around the X, Y, and Z axes respectively to make the position unchanged and the attitude change movement, and observe the robot motion state, angle, displacement and other data in an all-round way, and record the motion trajectory of each joint axis in real time, so that students can understand the robot motion state more vividly and vividly, and grasp the data more specifically and detailed.

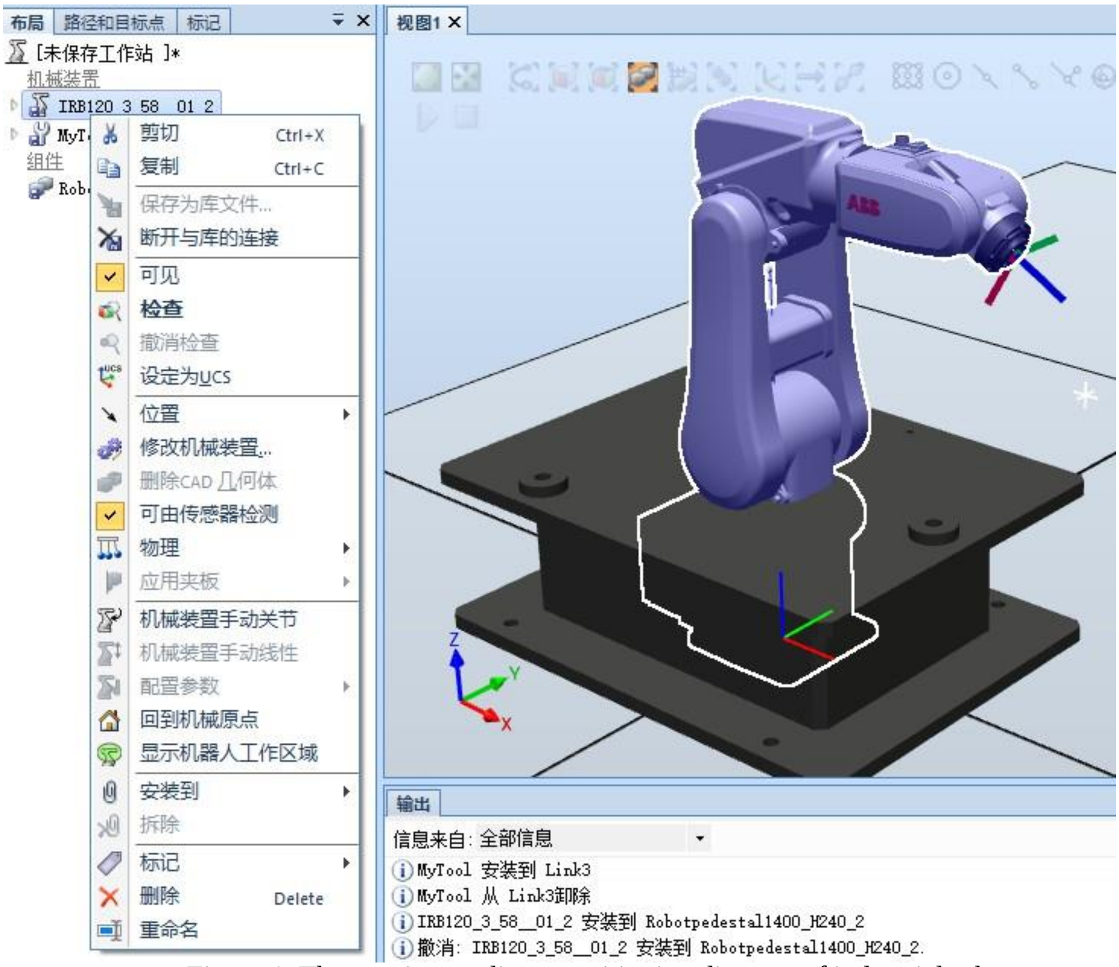

Figure 1. Three-axis coordinate positioning diagram of industrial robots

Robot workstation offline programming application, industrial robot programming is divided into online programming (teaching programming) and offline programming. Online programming needs to be carried out on the robot site, which not only occupies the robot resources, but also the accuracy of the teaching point depends on the experience of the on-site personnel, and there is a large error and low efficiency. Compared with online programming, offline programming can allow programmers to work away from complex and harsh environments and reduce work intensity. It can effectively avoid the occupation of robot resources, and the program can be easily edited and modified on the software side and transmitted to the robot controller for operation after normal debugging, which improves the programming efficiency. Combined with other industrial product design software, such as UG, Pro / E, etc., equipment or workpiece models can be imported into Robot-Studio, and workstations such as handling, palletizing, and assembly can be constructed, to guide students to think about workstation scheme design ideas in teaching, and organize teaching content such as layout implementation, process implementation, and system optimization, to improve students' ability to comprehensively apply industrial robot technology.

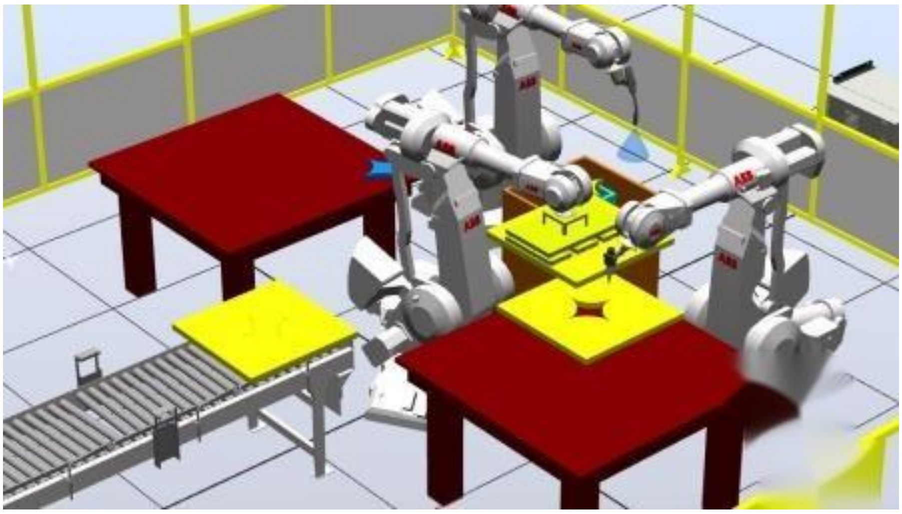

Figure 2. Processing diagram of the automatic production line of industrial robots

At present, the vocational college skills competition is one of the measures to measure the teaching level of vocational colleges, an important sign, as more vocational colleges have increased their investment in skills competitions to achieve the purpose of "promoting teaching through competition". "Intelligent Transformation and Integration Technology of Manufacturing Unit" is an emerging competition in the Vocational Skills Competition of Higher Vocational Colleges and has been successfully held for two national competitions so far. This competition aims at the intelligent manufacturing process of grinding, testing, processing, and other processes of automobile wheel hub parts, with the application of intelligent manufacturing technology as the core, and comprehensively examines the participating students' achievements in system integration design, application capabilities in industrial robot technology, visual inspection, and other technologies. The core module execution unit of the competition is based on the motion control of ABB robots, including the loading and unloading of quick-change tools, picking and storage of wheels, visual inspection, grinding and processing, etc., all of which need to use Robot-Studio for offline programming and virtual simulation, especially the process preparation of mass production wheels and customized production wheels, which can save a lot of time and improve the level of competition through software programming and debugging and then downloaded to the robot controller. The issue of whether the micro-lecture-based 'flipped classroom' teaching model is effective in the industrial robotics program of vocational schools was verified through a questionnaire survey conducted after the course. An anonymous survey was carried out with a total of 90 students from Class A and Class B. Ninety questionnaires were distributed and 90 were recovered, giving an effective response rate of 100% (see Table 2). According to Table 2, most students believe that the micro-lecture-based 'flipped classroom' teaching model can enhance their learning enthusiasm and change their learning attitudes. Under this new teaching model, it not only promotes learning ability and self-confidence but also improves teamwork skills. Students also think that this model can enliven the classroom atmosphere and enhance everyone's classroom expression abilities. A few students believe that they cannot complete all learning tasks under this teaching model. Overall, this model is highly recognized by students, and Classroom learning efficiency has significantly improved.

Table 2 Survey Results of Industrial robot teaching reform

Items	Agree	Neutral	Disagree
Increase learning motivation	96.42%	3.58%	0%
Liven up the classroom atmosphere	94.36%	3.18%	2.46%
Promote learning ability and self-confidence	86.45%	11.15%	2.4%
Enhance team collaboration and communication skills	78.89%	18.16%	2.95%
Lay the foundation for practical lessons	72.86%	24.78%	2.36%
Enhance classroom communication skills	80.64%	13.57%	5.79%
Able to complete all pre-class and post-class tasks	77.64%	10.25%	12.2%
Change the attitude towards learning	85.45%	11.23%	3.32%

Through the analysis of statistical data on the implementation effectiveness of diversified courses, it can be found that in terms of students' learning outcomes, the effects of learning align with the fundamental objectives of the course "Fundamentals of Industrial Robot Technology." Specifically, students have gained effective improvements in theoretical knowledge, technical skill mastery, and professional quality development through this course. Regarding students' course experience feedback, students showed high satisfaction with the course content, classroom format, and course resources, believing that learning in a flipped classroom under a task-driven context is enjoyable and fruitful.

CONCLUSION

The application of Robot-Studio software to the virtual simulation teaching of industrial robots can organically connect the professional courses, connect the core skills of the current industrial robot occupational job group, and promote the continuous development of the curriculum system in the direction of informatization of teaching methods and intensive teaching content. While using the powerful offline programming function of Robot Studio in teaching to realize the functions of workstation virtual simulation, system optimization design, offline programming, and debugging, it has played a good role in improving students' enthusiasm for learning industrial robots, cultivating students' patient and meticulous learning habits and good professionalism.

After presenting and organizing the key points of the course, the specific implementation of course development is carried out. This is the process of concretizing complex and abstract knowledge through task-driven methods. The main content includes two parts: 'selection of comprehensive training tasks for course development enterprises' and 'construction of the main line of task-driven course content.' The purpose is to integrate the thematic design of the course content into the real application scenario of the selected comprehensive training task 'assembly and handling of motor components on the production line,' based on the functional hierarchy division of the five major systems of industrial robots. This serves as an integrated training task throughout the course to combine course content with practical work, thereby creating a foundational course in industrial robot technology suitable for engineering students.

Experimental analysis shows that under the micro-lecture-based "flipped classroom" teaching model, the overall score distribution has a higher proportion of high scores and a lower proportion of low scores, with students' overall average grades significantly higher compared to the traditional teaching model. Survey results indicate that the micro-lecture-based "flipped classroom" teaching model can help stimulate students' learning motivation, has a positive effect on their attitudes toward learning, and is conducive to improving students' confidence, learning ability, teamwork, and communication skills. It also helps students approach problems from different perspectives and respond with a more positive attitude in their future studies and work.

This paper starts from the characteristics of industrial robot courses and the concept of running higher vocational colleges. In this paper, the teaching design and practice of the course were discussed by means of flipped classroom and virtual simulation software, according to the teaching mode of "integration of science, fiction and reality". It not only overcomes the problem of tight training resources, improves the utilization rate of industrial robot resources, but also enhances students' interest in learning and the role of virtual equipment in the learning process, and enhances students' ability to apply industrial robots.

Experimental analysis has shown that under the task-driven 'flipped classroom' teaching model, the proportion of high scores in the overall score distribution increases, the proportion of low scores decreases, and the overall average student performance is significantly higher compared to the traditional teaching model. The survey results indicate that the 'flipped classroom' teaching model, based on the virtual simulation software Robot-Studio, helps to stimulate students' learning enthusiasm, has a certain positive impact on their attitude toward learning, and is beneficial for improving students' confidence, learning ability, teamwork, and communication skills. It also helps students view problems from different perspectives and approach future learning and work with a more positive attitude.

Follow-up research should increase the application of curriculum development outcomes in actual teaching, further improve teaching content and plans through implementation results, and, if possible, invite more like-minded researchers to participate, promoting the research results to schools in more regions.

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