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Development of a Comprehensive Practical CAD Training Course based on Work Process Systematization

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Abstract. This paper adopts the theory of work process systematization to design and analyze the comprehensive practical training course on CAD through the study of the CAD comprehensive practical training course. This paper is guided by the theory of work process systematization course development paradigm, and the comprehensive practical training course is developed by analyzing the typical work tasks of real CAD technical workers. The course objectives of the comprehensive practical training course are formulated and strictly follow the typical work process analysis. The course objectives of the integrated practical training course were formulated by analyzing the typical work tasks of real CAD skilled workers, and the systematic curriculum development steps of work process analysis, learning situation design and teaching structure design were strictly followed, in which the real CAD was pedagogically processed, and multiple learning situations were systematically designed for comparative migration to enable learners to quickly learn comprehensive vocational skills and train them to master the methodological thinking of migration from typical work to universal work; finally, to ensure the smooth implementation of the integrated practical training course in the school, based on the integrated practical training course.

Keywords: work process; systematization; CAD; integrated practical training; curriculum development
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1 INTRODUCTION

With the development of computer technology, artificial intelligence, intelligent manufacturing, cloud computing, and other fields that have been widely used information technology, human beings have entered the "Internet +" era. The curriculum of CAD is mainly divided into theoretical and experimental parts, among which the theoretical part is not very different from the traditional computer, electronics, communication, and other science and technology majors, and the teaching theories, methods, and practical experience are abundant. The teaching theory, methods, and practical experience are very rich [1]. However, CAD is an evolving and closely integrated multidisciplinary subject, and considering the requirements of CAD talents in related industries, it is more important for CAD students to use rich experimental courses to develop practical, innovative and self-learning abilities in addition to mastering theoretical knowledge [2]. Therefore, secondary vocational schools have many pressing issues and problems in the process of exploring and reforming the practical training courses in their various majors in response to the development trend of the times. For example, most secondary vocational institutions are facing many problems, such as the level of students' knowledge reserves before enrollment is uneven, so the teaching programs and teaching standards of the practical training courses need to be improved [3]. Secondly, there is a certain degree of disconnection and gap between the training programs of industrial robotics professional practical training courses and the actual talents required by relative enterprises. Also, the ability level and teaching methods of individual teachers vary, resulting in different learning outcomes for students in the practical training courses. In general, various problems encountered in the implementation of practical training courses in secondary vocational and technical schools are discussed to solve the countermeasures. Based on much relevant literature, the practical training courses in secondary vocational and technical schools should be improved in terms of their objectives, teaching methods, and influencing factors. Because of the problems that the output of vocational education talents cannot meet the needs of enterprises under the background of CAD, the lack of collaborative comprehensive practical training, the single content of on-the-job internship and the low utilization rate of comprehensive practical training equipment in the practical training teaching of CAD in vocational colleges and universities, combined with the background of actual needs of enterprises and the training objectives of secondary CAD talents, based on the theory of systematic vocational education of work process, we develop a comprehensive practical training course and auxiliary equipment that meet the comprehensive skills training needs of modern CAD-related enterprises. Based on the theory of work process systematization vocational education, we developed a comprehensive industrial CAD training course and auxiliary equipment to meet the needs of modern CAD-related enterprises for comprehensive skills training. The comprehensive practical training course teaches real industrial CAD projects and systematically designs various work process-oriented learning situations to enable learners to quickly master comprehensive vocational skills, train them to master the methodological thinking of migrating from typical to universal work, and thus improve their sustainable development ability. It is expected that through the modular design of hardware and software, reserved space for key skills operation, and support for the multi-person collaborative operation, it can bridge the skills gap between practical training and actual CAD project implementation, effectively solve the problems of scattered knowledge system and lack of practical skills of secondary school students, and play an active role of "bridge" between schools and enterprises.

Planning a more systematic integrated practical training curriculum for CAD in secondary vocational education. At present, there are more studies on work process-oriented curriculum development, while there are very few cases of systematization-guided vocational education curriculum development: the former only uses the actual work process for teaching after one-time pedagogical processing, which often replicates a specific work process and is not conducive to the sustainable development of students' comprehensive vocational ability; while the latter takes the actual work process and deduces it into three or more logically related work processes for teaching following the laws of professional growth and cognitive learning. In the latter case, the actual work process should be taught more than three times according to the law of professional growth and cognitive learning, and then interpreted into more than three work processes with logical relationships for teaching. Therefore, the development and application of the comprehensive practical training course in this study will provide richer case materials for the related fields, and has certain theoretical significance for the research in the field of systematic curriculum development of work process and the practical training course of CAD in secondary school.

2 CURRENT STATUS OF RESEARCH

Relvas and Ramos [4] are the first to propose the idea of "action-oriented" vocational education, which enables learners to gradually acquire the ability to make and plan decisions in the work process while solving practical problems in the profession. Liu [5] pointed out that work process is different from the established applied knowledge systematized by disciplines, and generally refers to the search for the relevant typical job skills from the group of jobs corresponding to a professional field and the attempt to transform them into theoretical knowledge points. According to research of Wang and Bi [6], a work process is "a complete work procedure that is performed in an enterprise to complete a work task and obtain a work result". VO [7] through a lot of in-depth research, proposed that the basis of the work process-based curriculum design is the principle of rationalization and structured form of the curriculum content sequencing. Çelik et al. [8] proposed the design concept of work process systematized curriculum based on the successful experience of foreign vocational education curriculum and the German work process-oriented curriculum and developed and improved the design theory and design method of work process systematized curriculum. Higher vocational education aims to cultivate high-quality practical and skillful talents, and its cultivation objectives should have the dual attributes of both higher education and vocational education, which can reasonably and accurately locate the demand for cultivating senior professionals and also reflect the characteristics and requirements of both vocational education and higher education. From this, only by grasping and determining the talent cultivation objectives of higher vocational education in the general direction can we lay a good foundation for constructing talent cultivation mode and evaluation standards in the later stage. Therefore, a scientific and reasonable talent cultivation goal is very important for the whole vocational education. Only after determining the talent cultivation goal can we carry out a series of activities in the later stage, such as teaching system, practice system, curriculum setting, etc., and the construction of talent cultivation mode starts from here. We can see from the above positioning of talent training objectives that the problems are becoming increasingly prominent with the increasing requirements of talent training in higher vocational education. Taking Beijing as an example, it is mainly because the talent training objectives of higher vocational institutions are rather vague, some institutions, to pursue the popularization of theoretical knowledge, favor the cultivation mode of discipline system, draw excessively on the teaching system of higher education, and neglect the cultivation of practical ability. Although they emphasize on cultivating students' hands-on ability, they focus on cultivating only primary operation skills, so that students only acquire simple operation skills and lack the ability of sustainable development after graduation; on the contrary, some other institutions over-cultivate students' hands-on ability and lack the proper height and depth at the theoretical level, which does not meet the standard of higher education. Besides, the current higher vocational colleges and universities mainly focus on the specialist level and carry out less research on the corresponding undergraduate studies, especially no in-depth research on the orientation of cultivation objectives is carried out. In a word, the current higher vocational education talent cultivation mode generally has the problems of unclear orientation and unclear objectives, which seriously restrict the formulation and implementation of talent cultivation mode.

3 PROCESS SYSTEMATIZATION OF CAD INTEGRATED PRACTICAL TRAINING COURSE DEVELOPMENT DESIGN

3.1 Process Systematic Design

Systematic curriculum development based on the work process is the process of reconstructing and deconstructing the traditional course content. In the course content into the typical work, task process is the concept of reconstruction, the typical work, and knowledge of the linkage of key analysis, according to the typical work, theoretical knowledge to add or delete theoretical knowledge, what kind of knowledge is needed, the typical work task to arrange what kind of knowledge, declarative knowledge is complementary, procedural knowledge is the main. Disrupt the original discipline order, disrupt the original knowledge linked in a logical order, split into basic and separate knowledge points is deconstruction; around the typical work to determine the order of knowledge to organize course content. The organization of course content and the selection of course content are the two main elements of course development, and both refer to typical work tasks accordingly. The organic combination of theory and practice classes and the construction of an integrated science-practice curriculum has been a major trend in the secondary classroom. The integration of science and practice is the development of a systematic curriculum based on the work process connotation, based on the integration of science and practice for multiple teaching situations designed to complete work tasks, the implementation of diverse action-oriented teaching and evaluation [9]. In turn, to achieve effective training, enhance the level of professional ethics and professional knowledge and skills of students, to further improve the innovative thinking of students, to train students' comprehensive vocational ability and quality of the curriculum objectives, to lay a solid foundation for the future career development of students. In terms of curriculum development steps, there are five major steps. The first step is to conduct enterprise research and observation to record specific work tasks according to the identified courses. In the second step, typical work tasks are selected from the specific work tasks. In the third step, the action area is summarized, i.e., the typical work tasks are integrated into a comprehensive action area according to the complexity of the competencies, and the competencies necessary to complete the typical work tasks and the knowledge requirements implied behind them are analyzed through the requirements of the typical work. In the fourth step, the learning domain is converted, i.e., the action domain is reconstructed and converted into a professional curriculum to build the curriculum; in the fifth step, the learning context is designed, i.e., the learning domain is decomposed into thematic learning units according to the occupational characteristics. To a certain extent, the work process systematic curriculum development theory has clarified and solved the objective problems of curriculum design and development in vocational education, and is the most popular curriculum development paradigm in vocational education, as shown in Figure 1.

With the innovation and development of modern technology, work content, work forms, and work tools are increasingly diversified, which also puts forward higher requirements for workers, requiring them to have the ability of continuous innovation and continuous learning. Vocational education cultivates students with a better overall quality, who can quickly adapt to the actual workplace and even become professionals in their field. Therefore, schools should specifically analyze the work tasks of vocational jobs as the entry point, and the learning content should focus on typical work tasks to cultivate students with the ability to continuously learn and innovate, learn to strengthen communication, collaboration, and the ability to analyze and solve problems in the specific work process, and cultivate students' comprehensive professional abilities and qualities in an all-round way. It should be clear that vocational education means that the school should train students not only with very professional vocational skills, but also with certain practical experience, with high quality comprehensive professional skills, and able to quickly adapt to and be competent in their jobs.

Each work task is a complete work task based on the real situation of the enterprise, in the course of curriculum development should be based on the needs of students, the actual needs of enterprises as the starting point, not only focus on the students' learning acceptance but should pay great attention to the students' learning methods, vocational ability, innovative thinking training. Therefore, we must break the traditional solidified vocational education thinking and education methods, and effectively improve the effectiveness of teaching. The real purpose of teaching is to enable students to better adapt to work, so the curriculum development should be oriented to the work process, through the cooperation between schools and enterprises, to systematically plan the learning process and learning content for students, increase the opportunities for students to work and practice, so that they can systematically digest the theoretical knowledge in books through practice, increase and enrich their practical work experience, so that they can We also provide a solid foundation for students to quickly adapt to the workplace.

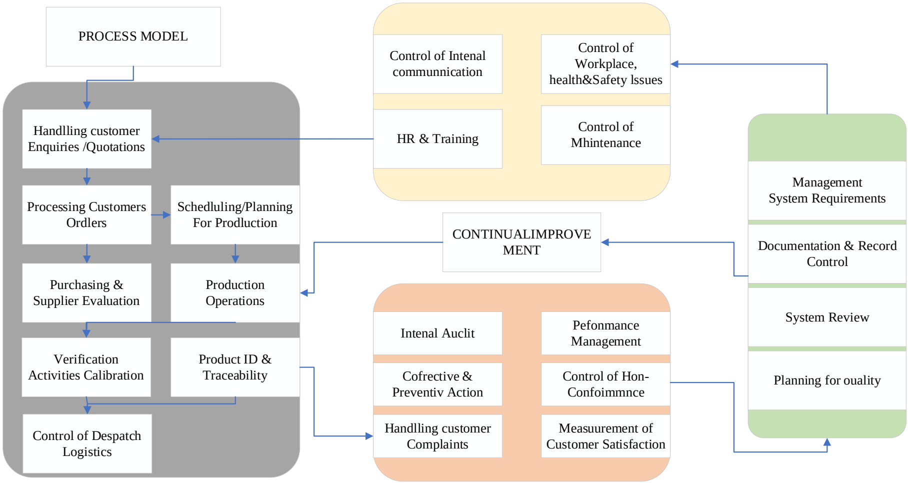

Figure 1: Process systematization model.

The purpose of the job research is to identify the specialties for which courses are offered, conduct field research on the jobs corresponding to these specialties, and select representative typical jobs from among all the jobs. The overall work is reflected by typical tasks. The course developers cannot fabricate typical work tasks, but can only be derived from real enterprises and need to have a complete structure of the work process. The quality of the course is directly influenced by the selection of typical tasks. As one of the important bases for setting course objectives, the selection of typical tasks is also an important part of course development. Comprehensive action areas are integrated from typical work tasks according to the complexity of the competencies, analyzing the requirements of typical work and the competencies necessary to complete typical work tasks. Its basis is the typical work task, based on the principle of consistent action dimensions and the same nature of work, the integration of typical work tasks to establish an integrated learning area. It contains a variety of contents such as methods and processes of the job, work tools, etc. The requirements of different types of work tasks are analyzed in specific detail and course names are developed. After building the basic system framework of a professional curriculum, according to the methods and principles of work process systematic curriculum development, for each learning area, that is, for each learning chapter must then carefully design the content and context, decompose the learning area into multiple interrelated thematic learning units. Although the work to be completed between each learning context independently separate, these different learning contexts together throughout the learning area, but also only a part of the typical work tasks. Learning contexts can be designed in a spiral format, where each learning context is a complete work process, with an emphasis on repetition of the work process approach, with the same dimensions between learning contexts juxtaposed with each other, or where the previous learning context contains the next learning context.

3.2 CAD Integrated Practical Training Course Design

To test the effectiveness of the CAD course based on work process systematization, the author selected the students of the CNC 1 class of grade 18 in my internship school to carry out an experimental study of teaching and learning at the micro-level. There were 40 students in CNC 1 class, and before the experiment, the students in CNC 1 class were divided into two groups, defined as CNC 1 group (experimental group) and CNC 2 group (control group), and the overall knowledge level of the students in the two groups was equal. In this experiment, CNC 1 group adopts a systematic curriculum teaching based on the work process, and CNC 2 group adopts the teaching mode of theory. The advantages of the systematic work process-based curriculum were analyzed and compared by teaching both groups the same teaching content - the machining of integrated parts - followed by an assessment of integrated part machining and related theoretical knowledge. After a period of learning, students have mastered the basic programming instructions and can use the instructions to write programs, can read the part drawing, can reasonably select tools, gauges and fixtures, and other related tools and fixtures according to the requirements of the part drawing, and can safely carry out part processing [10]. The teaching process is based on lecture and teaching methods. The teaching process is a combination of lecture, task-driven method, group discussion, role-play, demonstration, and simulation methods. The concept of course carrier was first introduced in the work process systematization course, and the course carrier is the concretization of the learning situation, which refers to the form of carrying effective information presented in material or immaterial form through the pedagogical transformation of the characteristics of the typical work process. Transferring this concept to the study of the development of a comprehensive practical industrial CAD course with systematic work processes, the carrier of this practical course is the auxiliary practical training equipment presented in material form, and the design of the course carrier is the realization process of the migration of the comprehensive practical training course in a tangible learning situation, and the design of the comprehensive practical training equipment will be based on the principles of the course carrier design.

Transferability emphasizes the need for typicality and representativeness of the design vehicle and requires exemplary features. The principle of "transferability" can be understood as the typical presentation of industrial CAD projects and the typicality of the working process in different learning contexts in combination with the industrial CAD integrated training courses that have been designed and developed. Therefore, the integrated training equipment should achieve the following two goals: the integrated training equipment should be highly realistic and simulated, and the CAD training equipment should be highly modularized to build an industrial CAD project engineering architecture with perception, network, and application layers, and provide relevant hardware and software equipment to simulate the actual industrial CAD project implementation.

Each learning situation of the comprehensive industrial CAD training course contains 5 work sessions (educational typical work tasks), and the training equipment should meet the requirements of drawing wiring diagrams (like the implementation of drawing wiring diagrams is less demanding and can be completed in any computer room, the training equipment requirements of the typical work tasks are not required here), integrated wiring, equipment installation and configuration, system configuration and commissioning, and platform management. Maintenance of teaching requirements: comprehensive wiring class typical tasks mainly include the layout of wired and wireless communication lines, comprehensive training equipment should be easy to network deployment, networking, and expansion, only less manual intervention and configuration, you can quickly set up the network and start working properly. Equipment configuration class typical work tasks are mainly used to train students on a variety of intelligent meters, sensors, and other industrial data collection equipment installation, configuration, and commissioning skills. Comprehensive training equipment needs to have the corresponding functional modules to support a variety of meter, sensor-related experiments, equipment can be packaged inside the supporting instruments and equipment to facilitate the direct operation of students and configuration of common industrial CAD data acquisition equipment.

4 ANALYSIS OF RESULTS

4.1 Comprehensive Practical Training Equipment Practical Application Effect

To verify the effectiveness of the work process systematized industrial CAD integrated training course and supporting equipment, four interns from the enterprise industrial CAD project were selected for the study. Four interns were divided into two groups, each consisting of two students, and the two groups were briefly tested for their professional and technical abilities before the experiment, and their skills and knowledge were equal. The other group received two weeks of intensive training in a systematic work process training course and then participated in a two-week internship in an industrial CAD project. At the end of the one-month internship, the final assessment was based on the ability to perform typical tasks in a combination of written exams and interviews, all involving the five major aspects of the implementation of the industrial CAD project (drawing wiring diagrams, integrated wiring, equipment configuration, and installation, system configuration and commissioning, and platform management and maintenance).

The written test mainly assesses the overall planning ability of an industrial CAD project, requiring the experimenter to describe in words the key technologies, instrument standards, wiring design, and maintenance requirements, and other important processes of the corresponding project; the interview is presented in the form of a field trip, mainly to test the practical operation ability of the experimenter, the teacher observes the students' operational proficiency, standardization. The teacher gives the score on the spot by observing the students' proficiency, standardization, etc. After combining the results of the written test and the interview, the two groups of students were evaluated in terms of their ability to perform typical work tasks. Among them, 0% indicated that they had never been exposed to the typical work task, 25% indicated that they were exposed but only involved in simple mechanized operations, 50% indicated that they mastered the basic skills of the typical work task, 75% indicated that they could operate the typical work task proficiently, and 100% indicated that they could innovate based on the existing ones. The analysis comparing the degree of proficiency in the practical skills of the two groups of interns at the end of the practical training is shown in Figure 3.

The control group, during their internship in the enterprise, could only access mechanical skill-based jobs such as integrated wiring and equipment configuration and installation and had less access to complex work tasks such as drawing wiring diagrams, system configuration and debugging, and platform management and maintenance, and they could not systematically master the comprehensive skills of the industrial CAD project, nor could they master the typical work tasks in the complete project skillfully.

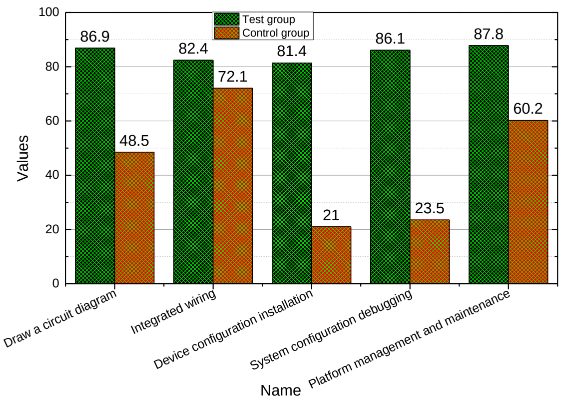

Figure 3: Comparison of typical work task realization capabilities.

By assessing two groups of students on the task of integrated parts machining, the task required students to work in groups of four to cooperate to complete the integrated parts machining, and finally to conduct a task summary report. In the process of the task, the group members divide the work and cooperate to first acquire the knowledge related to the machining of integrated parts, then develop the machining plan, implement the plan, complete the relevant task sheet, and finally complete the machining task and conduct a summary evaluation. This shows that a systematic curriculum based on the work process makes it easier for students to grasp what they have learned, greatly shortens the time to complete the task, reduces the cost of time, and shortens the cycle of training operators with comprehensive vocational skills and qualities, as shown in Figure 4.

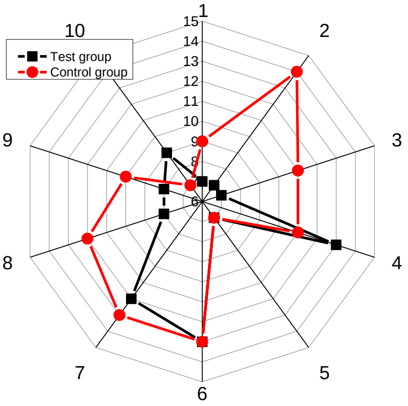

Figure 4: Completion time statistics.

In the subsequent assessment of theoretical knowledge of the learned contents, the same examination questions were given to both groups, and the distribution of the scores was compared to Figure 5. From the average scores of the two groups and the comparative distribution of the scores, the students of CNC group 1 had a better proficiency in the learned theoretical knowledge and a stronger memory than the students of CNC group 2.

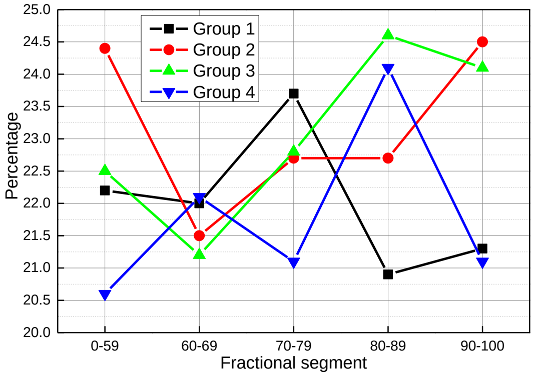

Figure 5: Achievement distribution chart.

The problem of students is that some students are used to passively accept knowledge, independent learning ability, independent thinking, communication, analysis, and problem-solving ability is poor, for the work process-based systematization course implementation process of information, decision-making and planning link is not very good grasp; secondly, some students also exist on their role as the role of the role is not clear enough. The use of a work process-based systematic curriculum for teaching students can effectively improve the problems that exist, as the course continues to advance so that students in the independent learning ability, independent thinking, communication, analysis, and problem-solving have been exercised. First, students themselves should change their attitude towards learning, from the previous passive acceptance to the active solicitation, and actively participate in the course, while also considering their future career development. Secondly, teachers should not only pay attention to the transfer of knowledge in the teaching process, but also pay attention to the cultivation of students' comprehensive vocational ability, pay attention to students' characteristics, teach students according to their abilities, explore different potentials in students, and let them develop comprehensively; teachers can organize visits to enterprises from time to time to learn about different positions and work processes in enterprises, so that students can have certain knowledge about the positions they want to engage in in the future. At the same time, it can also better promote the teaching effect.

4.2 Analysis of Work Process-Oriented Results

With the development of society, the demand for computer professionals and technicians in various fields has transitioned from basic and capable of general maintenance and repair to professional technicians who need to have certain development ability, design ability, maintenance ability, and management ability. Therefore, the talents of computer application technology majors will have a wider employment prospect and also face severe employment pressure. The evaluation of the graduates after the higher vocational data survey of 27 enterprises is shown in Figure 6.

Graduates from higher vocational colleges and universities meet the needs of the work they are engaged in terms of mastering professional knowledge. However, for computer companies, students' professional knowledge and practical operation ability are still limited and need to be strengthened. In computer companies, pay much attention to the cultivation of cooperation consciousness, and pay special attention to the communication and coordination, teamwork spirit. Students are still lacking in these aspects. Besides, for the rapidly developing computer industry, the ability to innovate is a necessary trait, and students are still generally lacking in the ability to innovate.

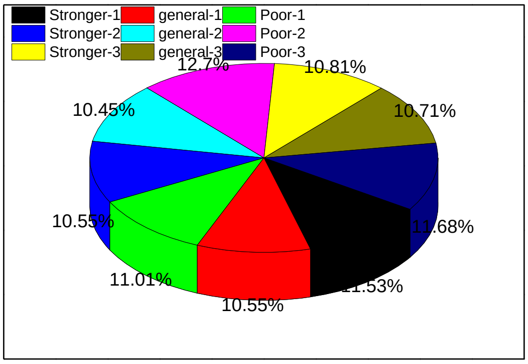

Figure 6: Survey analysis results.

In the teaching team, the subject leader should be designated, and the subject leader should lead the professional teachers' team to prepare and adjust the teaching program, and the subject leader is suggested to be the front-line technical experts from enterprises. And build teacher training and training bases to do more training for existing teachers, while government support is needed to improve teachers' treatment, as shown in Figure 7.

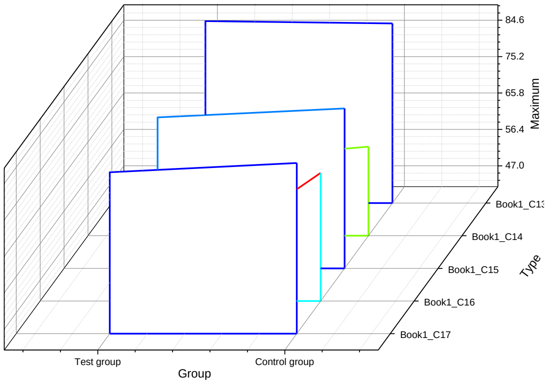

Figure 7: Average score of theoretical knowledge performance.

The problem in teaching resources is due to the limited teaching conditions in schools, the teaching process is not fully equipped with teaching equipment, not in the same site, affecting the coherence and time of teaching. Faced with this situation schools can solve the problem by adding teaching equipment, improving teaching facilities, and building a teaching site for the integration of science and practice, or by building off-campus practical training bases with enterprises.

Based on the quantitative analysis of national competition results, the training of core computer skills and related courses are still necessary for school students, but they only face the problem of how to keep up with the times and keep up with the current trend. Compared with basic and single computer skills, students are weaker in comprehensive and open-ended task solving skills, and the gap between different students and schools is more obvious, as shown in Figure 8.

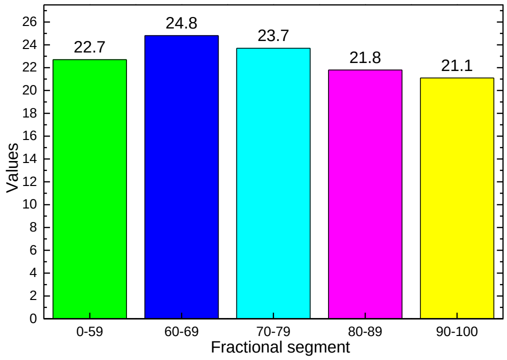

Figure 8: Number of schools by score range.

The proficiency in basic knowledge helps students to solve comprehensive tasks, but better basic skills do not mean a better ability to solve comprehensive tasks. Higher vocational students are not only not weaker than undergraduate students, but even surpass them in the application of information technology ability. Facing the growing market demand in information technology, only by letting students get exercise in all aspects in the institutions and master the technology needed by the enterprises, can students be trained into talents needed by the society and form a complete development channel; at the same time, we should subdivide all aspects of talents training, make targeted strategies, always learn from the advanced talents training experience at home and abroad, and discard the talents training experience of higher vocational institutions that do not meet the market development rhythm. At the same time, it is necessary to subdivide all aspects of talent cultivation, formulate targeted strategies, always learn from the advanced talent cultivation experience at home and abroad, abandon the talent cultivation mode of higher vocational institutions that do not adapt to the pace of market development, and keep pace with the times in time, to solve the problem of matching the graduates of higher vocational colleges with the needs of enterprises, and thus really improve the quality of computer application technology professionals.

5 CONCLUSION

In this paper, based on the analysis of the literature on "work process systematization" in vocational education and the current teaching situation of CAD professional training courses, we design and develop a comprehensive industrial CAD training course and auxiliary equipment based on the paradigm of work process systematization course development. Most of the tasks in the learning situation can be realized in the indoor environment of the school or the enterprise through the training equipment, and some of the basic tasks such as integrated wiring, project cognition, and equipment installation, which require high environment and are related to project investigation, can be trained in the real environment of the enterprise. The emergence of practical training equipment effectively solves the problems of single content of students' top-level internship and difficulties in accessing typical work tasks. Through the flexible combination with the real environment of enterprises, the enterprise interns of middle-level CAD majors are clearer about the occupation they will engage in and show higher motivation in the practical training courses. The evaluation is guided by the project results, and the evaluation results are intuitive. The group can negotiate and communicate proactively to complete the project tasks successfully and not lag other groups, and they gradually internalize their knowledge and skills and take the initiative to learn new skills to operate to solve the problems.

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