IOSR Journal of Research & Method in Education (IOSR-JRME)
e-ISSN: 2320–7388, p- ISSN: 2320-737x Volume 13, Issue 4 Ser. III (July. – August. 2023), 51-59
www.iosrjournals.org

Research and Practice of An Engineering-Driven Training System for Improving the Core Abilities of Applied Mechanical Majors

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ABSTRACT:
In response to the shortcomings of inaccurate target positioning, mismatch between teaching content and industry demand, and gaps in innovation and entrepreneurship training in the cultivation of applied mechanical majors in China, a project-driven training system for improving the core abilities of applied mechanical majors has been constructed. The system focuses on the cultivation of professional core abilities of design, strong operation, innovation and entrepreneurship. It improves the engineering-driven teaching effect by creating course resources, improves professional practice ability by building platforms, and promotes scientific research literacy by strengthening innovation. The practical teaching effect shows that in the past five years, not only the practical abilities of the students have been significantly improved, but also the awards in subject competitions, the publication of scientific research papers, and the application for patents have all been significantly improved, which verifies the effectiveness of the training system.

Key words: *Mechanical major; Core competencies; Engineering driven; Innovative practice; Training system*

Date of Submission: 08-08-2023 Date of Acceptance: 18-08-2023

I. INTRODUCTION

Professional core abilities directly determine the employment competitiveness of students, as well as the sustainable development and competitive advantages of later careers. Affected by the representation of the knowledge system in traditional teaching, the phenomenon of emphasizing knowledge and neglecting practice in the existing talent training is still common, and the teaching content is relatively outdated and lagging behind. After employment, students generally feel that the professional knowledge they have learned is disconnected from the new development of industries and new technologies in enterprises, and cannot meet the needs of job positions. In addition, the current talent training mostly adopts a fixed training model from the classroom to the laboratory, and innovative training emphasizes more on subject competitions, with limited training guidance methods. Therefore, it has become a consensus in higher education to effectively improve students' core professional abilities and enable them to better adapt to job requirements.

Applied universities have taken the lead in actively exploring reforms. Song SH *et al.* from Jiujiang University proposed to strengthen the cultivation of students' engineering practical ability by building a comprehensive education platform, strengthening practical teaching, and deepening science and education [1]. From the perspective of new engineering, Xu XD *et al.* from Changchun Institute of Technology, taking the practical experience of the reform of the applied talent training system for mechanical majors as an example, proposed a training path for applied talents based on "integration between specialty and innovation, integration between production and education, integration between industry and education" [2]. Wang Na *et al.* from Shenyang Urban Construction College, for their mechanical professional group, under the guidance of the integration between introduction and education, reformed the talent training model through measures such as professional optimization, curriculum system and teaching content reconstruction, and teaching practice improvement, so as to meet the needs of local industry transformation and development for high-quality applied talents [3]. Li Lin *et al.* from University of Science and Technology Beijing had built a practical teaching system of robotics engineering with integration between industry and education by transforming scientific research achievements into industrial robot technology training courses, building an online "cloud class" platform, and encouraging students to participate in various competitions to achieve a combination of competition and teaching [4]. On the basis of analyzing the problems and challenges existing in the training of applied talents in mechanical major, Bai Bing from Dalian Polytechnic University carried out the research on the training model of applied talents in the context of integration between industry and education through the implementation of project centered curriculum design, industry-university cooperation and subject innovation competitions [5]. Xie Fang *er al.* from Nanyang Institute of Technology had cultivated the professional core ability of mechanical students by constructing a skill competition course system and improving experimental resources [6]. Han Xingguo *et al.* from Guilin University of Aerospace Technology realized the cultivation of professional core abilities by modularizing mechanical professional courses and modifying course content [7]. Li Zhonggang *et al.* from Beijing Information Science and Technology University had cultivated innovative and applied talents by improving the practical teaching system in class and strengthening extracurricular technological innovation [8]. Engineering ability-oriented engineering education is prevalent in Europe and the United States. For example, Worcester Polytechnic University in the United States had developed a student-centered, project-driven, and result-oriented engineering education [9]. Germany cultivated applied talents by implementing the "dual ausbildungs system" education model in higher education [10]. France attaches great importance to the cultivation of applied practical ability by strengthening the joint training with enterprises in the engineer stage of higher education [11].

With the proposal of "Made in China 2025", China is moving from a big manufacturing country to a powerful country at a high speed. At the same time, the society's demand for students majoring in mechanical engineering has changed from quantity to quality. Building an engineering-driven training system for improving the core abilities of applied mechanical majors, combining new products and new technologies with courses, and updating teaching content and explaining knowledge points through engineering cases will help students better adapt to future positions. Self-constructing skill training platforms to strengthen practical ability in practice, and cultivating innovation ability in a refined manner through multiple simultaneous and collaborative progressive measures will help improve the effect of talent training and better serve the local economy.

II. CONSTRUCTION OF ENGINEERING-DRIVEN TALENT TRAINING SYSTEM

The engineering-driven talent training system oriented to the improvement of professional core abilities is based on the talent training orientation of the school where the major is located, and is constructed from the professional ability composition and improvement needs of applied mechanical students. The system is shown in Fig. 1.

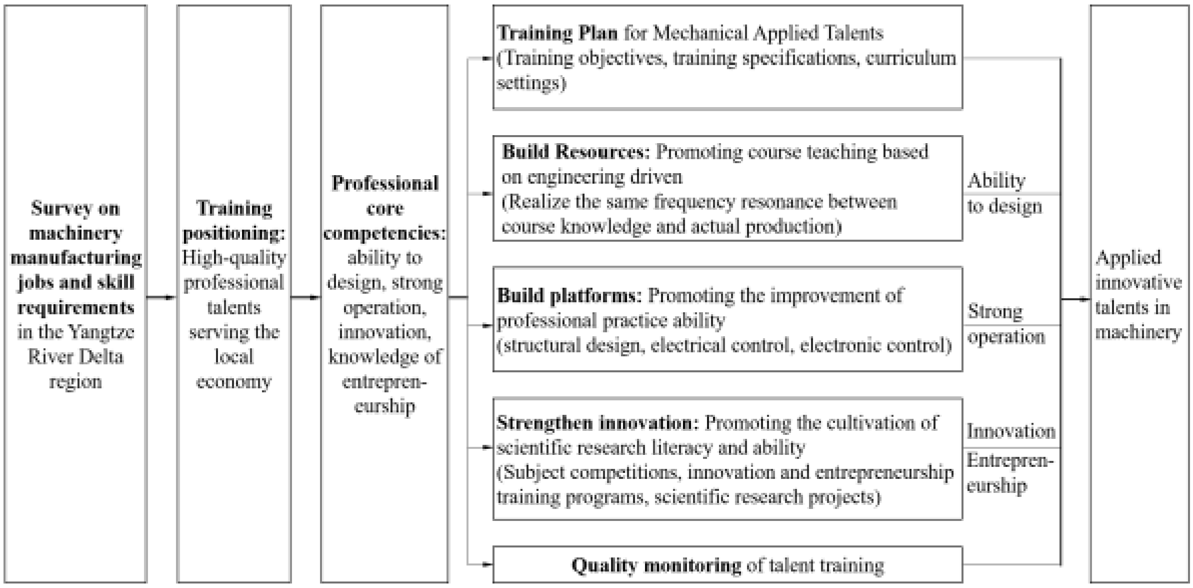


Fig.1 Talent training system for applied mechanical majors

In this system, the job demand of the machinery manufacturing industry in the Yangtze River Delta region is taken as the guide. The core professional ability training of "being able to design, strong operation, innovation, and knowledge of entrepreneurship" is taken as the goal. Under the guidance of talent training plan and quality monitoring, the progressive training of mechanical major is realized through the same frequency response between course knowledge and actual production, engineering-driven teaching based on multiple platforms, and innovative quality training, and then thereby forming a new mechanism for the cultivation of applied mechanical talents that integrates "operation → skills → competition → innovation → entrepreneurship". Furthermore, a new mechanism for training applied mechanical talents based on the integration of "operation → skills → competition → innovation → entrepreneurship" has been formed.

III. BUILD RESOURCES AND PROMOTE COURSE TEACHING BASED ON ENGINEERING DRIVEN

The research group closely focuses on the core of "mechanical" and "electrical" professional ability training in the talent training of mechanical students, and builds three core competency course groups including "mechanical design", "electrical control" and "electronic control", as shown in Fig. 2. Then the members of the research group are organized to carry out the engineering-driven teaching reform of each core course from the aspects of teaching content, teaching methods, teaching means, and built corresponding engineering teaching case resources, as shown in Fig. 3. Through inspiring teaching cases, students' interest in learning is stimulated; through cognitive teaching cases, teaching key points and difficulties are interpreted; through design-based teaching cases, students' application ability of course knowledge points is improved. Case-based engineering-driven teaching can effectively help students understand and master the knowledge points of the course.

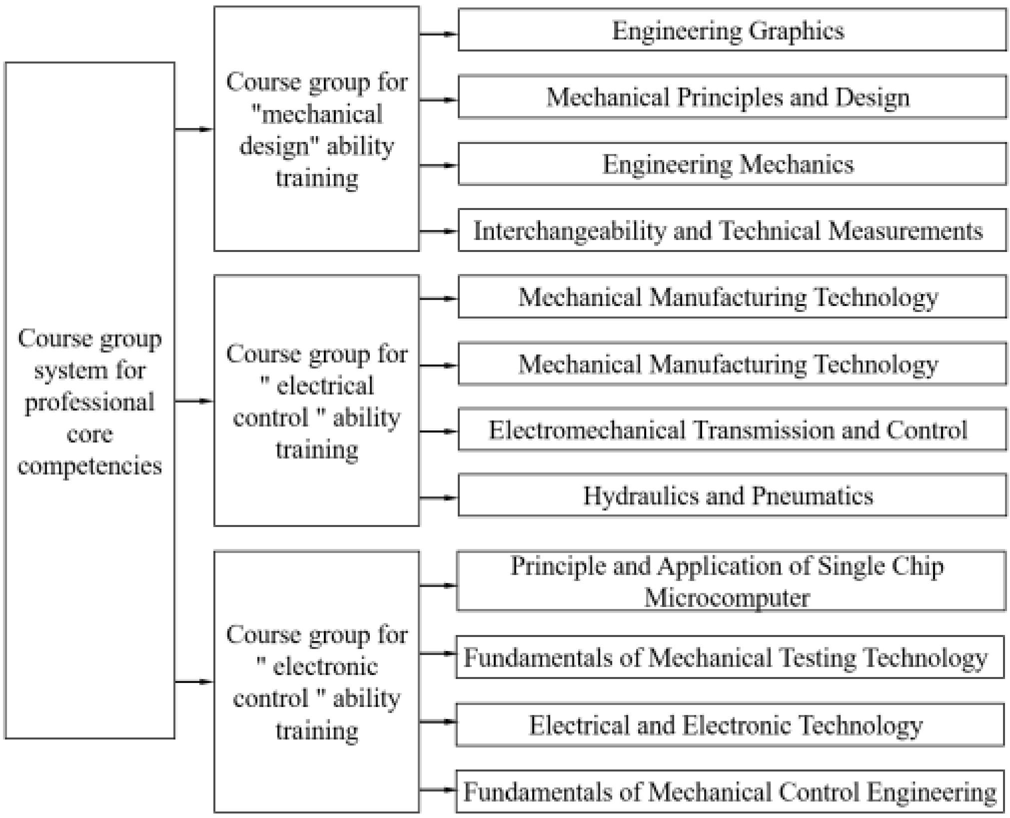


Fig.2 Course group system for professional core competences

Fig.3 Engineering teaching cases of some core courses

IV. BUILD A PLATFORM AND STRENGTHEN PROFESSIONAL PRACTICAL ABILITY

In order to help mechanical students in our school apply course knowledge, especially to strengthen their practical abilities, the research group focuses on the centralized professional practice in the talent training plan and independently builds corresponding engineering training platforms, including virtual training platforms, hardware training platforms, and guidance materials, as shown in Fig. 4, which improves the effect of students' professional training and strengthens the cultivation of various practical abilities. Some main platforms are as follows.

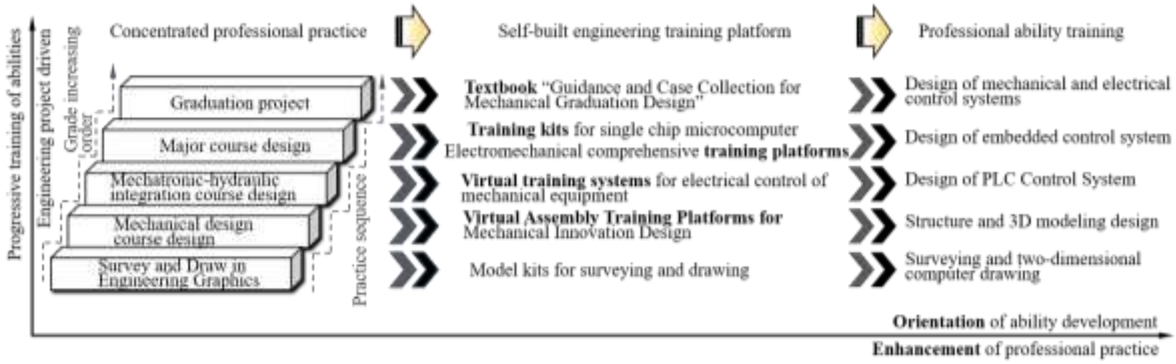
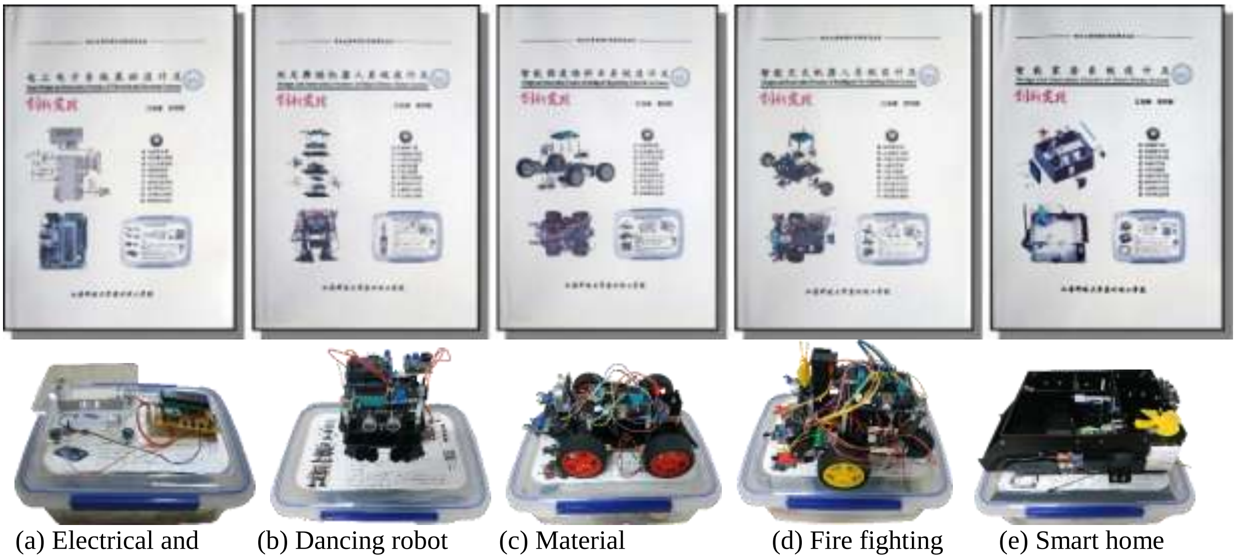


Fig.4. Construction system of major practice platform

Project innovation training kit for SCM (Single Chip Microcomputer) control

For practical courses such as "Major Course Design", our research group has developed a series of project training packages for SCM control as shown in Fig. 5. These packages include a total of five, namely electrical and electronic basics, dancing robot, material dispatching vehicle, fire fighting robot and smart home. During the practice, students can carry out the mechanical structure design, 3D modeling and production of the projects; the circuit design, simulation and program debugging of the functional modules of the projects; the overall circuit design, simulation, program design and experimental testing of the projects, etc. Based on the practice of projects in the packages, students' system concepts and engineering awareness can be effectively cultivated, and their ability to comprehensively apply the knowledge of single-chip microcontrollers to solve practical engineering technical problems will be improved.

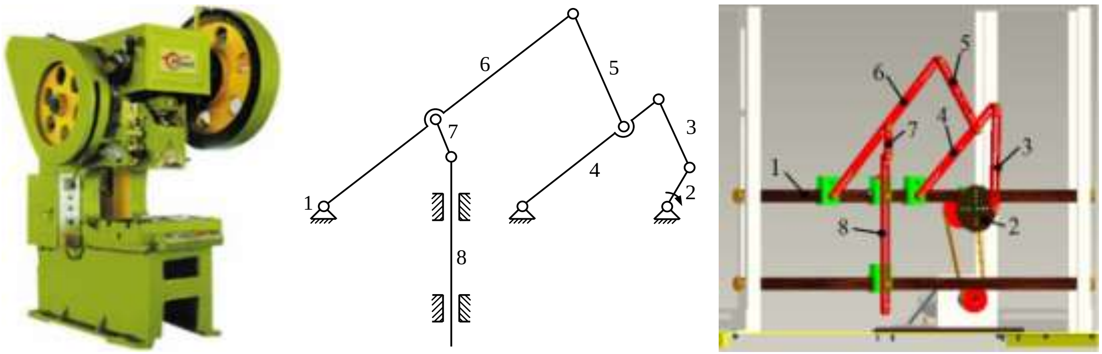


(a) Electrical and electronic basics (b) Dancing robot (c) Material dispatching vehicle (d) Fire fighting robot (e) Smart home

Fig. 5. Project innovation training kits for SCM control

Virtual assembly training platforms for mechanical innovation design

Focusing on the "Course Design of Mechanical Design", combined with the equipments in the newly built modern mechanical innovation design laboratory, the research group has independently developed a series of virtual assembly training platforms for innovative design of engineering objects based on the Pro/Toolkit secondary development module provided by PTC. Fig. 6 is the virtual assembly of punch presses carried out by students based on the built virtual assembly platform.

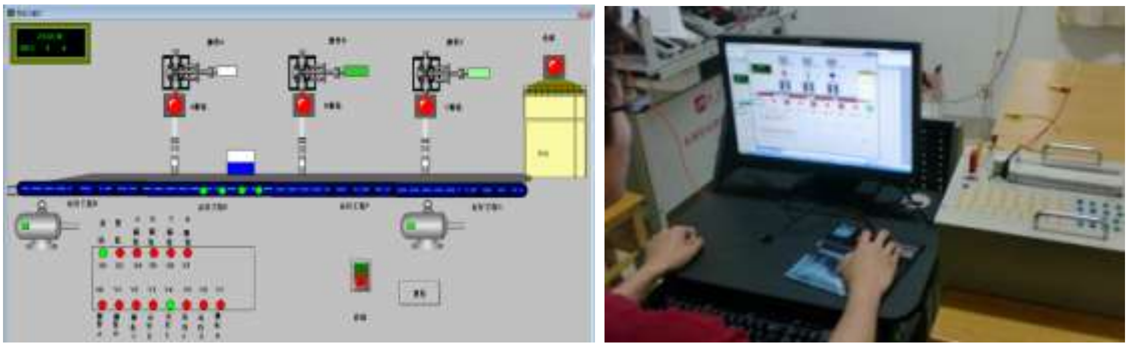


(a) Entity diagram (b) Simplified diagram (c) Virtual assembly diagram

Fig. 6. Punch press and its virtual assembly

Virtual training system for *Electrical Control of Mechanical Equipment*

Under the limited hardware equipment resources, in order to improve the practical teaching quality of the mechatronic-hydraulic integration course design, the research group independently developed 5 sets of simulation training systems based on MCGS configuration software. Fig. 7 is the self-developed engineering case of the assembly line and shows the students' practical training. Students can independently write ladder diagrams for control system training based on control requirements and tasks, as well as PLC I/O point allocation, which improves students' interest, enriches practical content, meets teaching requirements, and achieves the ladder diagram program training effect of the mechanical equipment electrical control course.



(a) Simulation training system (b) Student training status

Fig. 7 Engineering case based on assembly line

V. STRENGTHEN INNOVATION AND PROMOTE THE IMPROVEMENT OF INNOVATION PRACTICE ABILITY

In order to further cultivate students' innovative practical abilities, our school has always attached great importance to the development of the second classroom, and has developed a system for cultivating students' extracurricular innovative practical skills based on "extracurricular subject competitions", "entrepreneurship and innovation plans", and "scientific research projects", as shown in Fig. 8. The system embodies the characteristics of "step by step, continuous improvement, layered training, and emphasis on innovation".

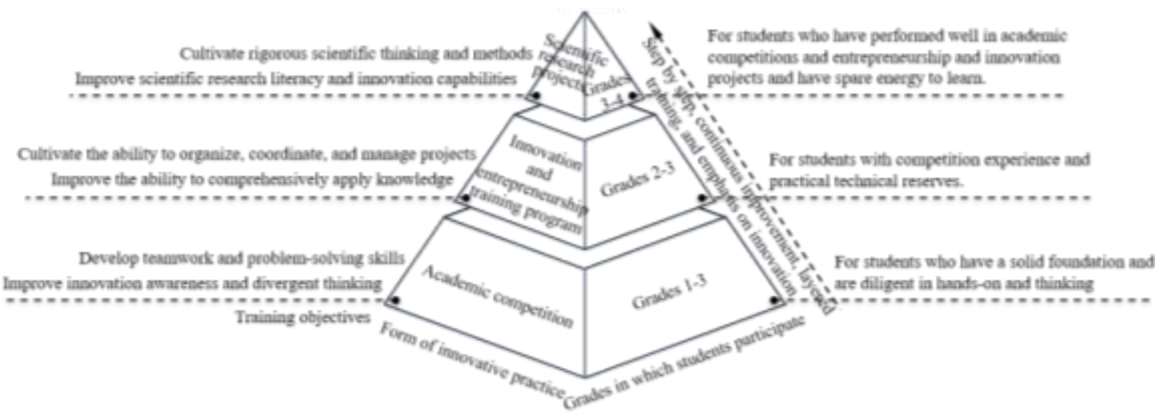


Fig. 8 The training system of extracurricular innovative practice for college students

Construct extracurricular subject competition platform and its organization and operation system

Through the competition, the cultivation of students' awareness of technological innovation is driven, and the comprehensive application of professional knowledge, the training of teamwork awareness, and the improvement of the ability to solve practical problems are realized in the competition. In our school, on the one hand, relying on the innovation practice base, the competition laboratory shown in Fig. 9 has been built; on the other hand, campus competitions such as charming robots and smart car tracking, as shown in Fig. 10, are actively carried out to create a competitive atmosphere among students and select outstanding talents to participate in the competition.

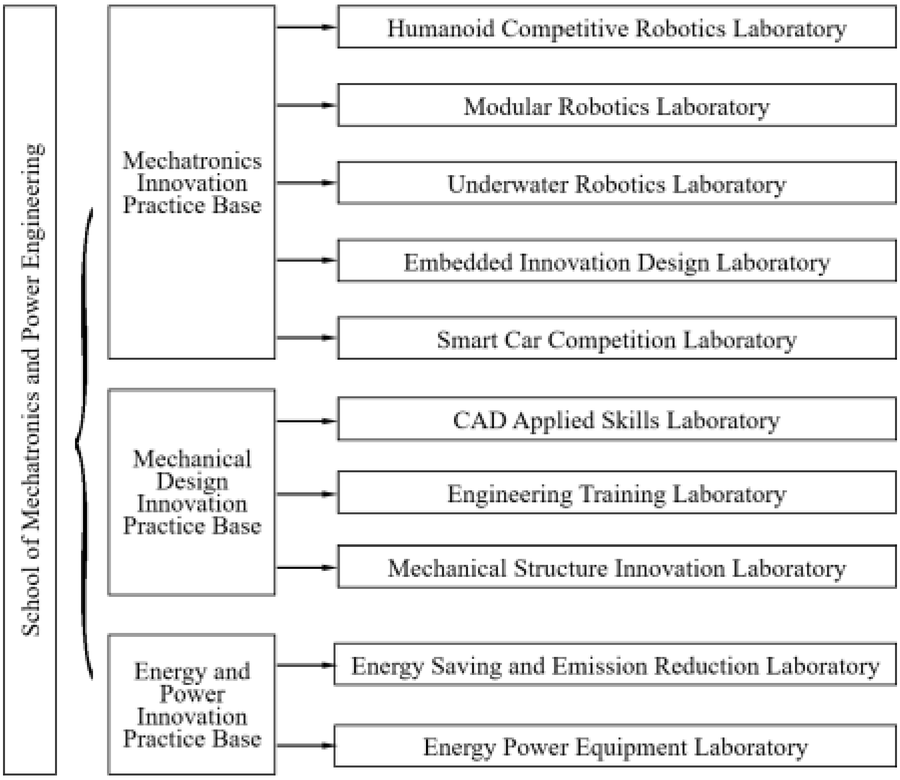


Fig. 9 Competition laboratory

(a) Charming robot (b)Smart car

Fig. 10 Campus competitions

Relying on the competition laboratory, our school organizes students to participate in more than ten competitions every year. In order to improve the cultivation effect of students' innovation ability based on extracurricular subject competitions and increase the input-output ratio of our school, the organizational operation system of the competition laboratory, as shown in Fig. 11, has been formulated. From the figure, it can be seen that the organization and operating system are mainly managed by students themselves. The school is mainly responsible for supervising daily operations and funding operations, and adopts the "old to new" assistance and inheritance to promote the healthy development of the laboratory.

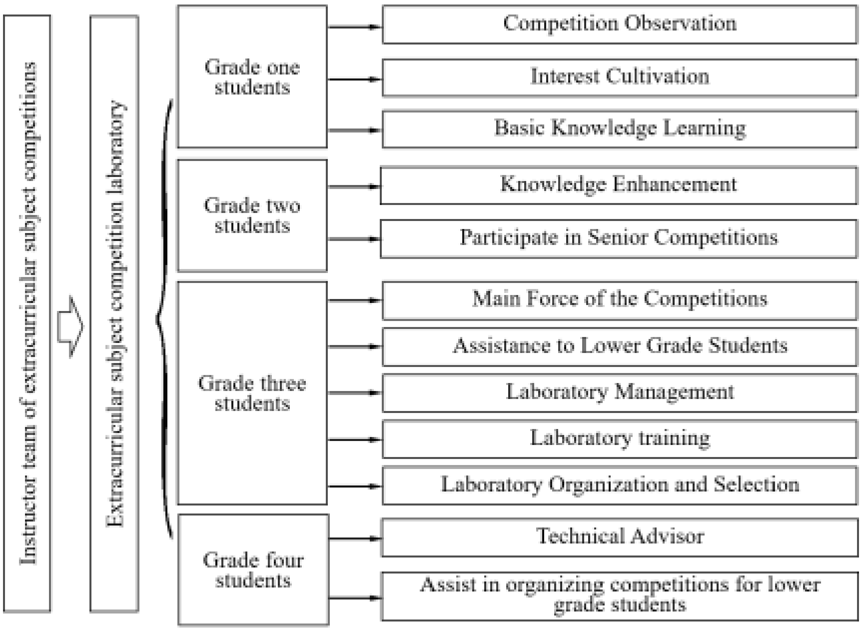


Fig. 11 Organizational and operational system of competition laboratories

Construction of Innovation and Entrepreneurship Training Plan Platform and Its Guidance System

The "Innovation and Entrepreneurship Training Plan" platform is mainly for students with competition experience and practical technical reserves. It starts with actual engineering, with students as the mainstay and teachers as the assistant. Through the complete process of scientific research or entrepreneurship such as project application, approval, execution and conclusion, students' engineering design awareness is cultivated, and students' project organization, coordination, management and technological innovation abilities are improved. In order to better help students develop innovation and entrepreneurship training programs for students, our school has established a relatively mature guidance system for innovation and entrepreneurship training programs, as shown in Fig. 12.

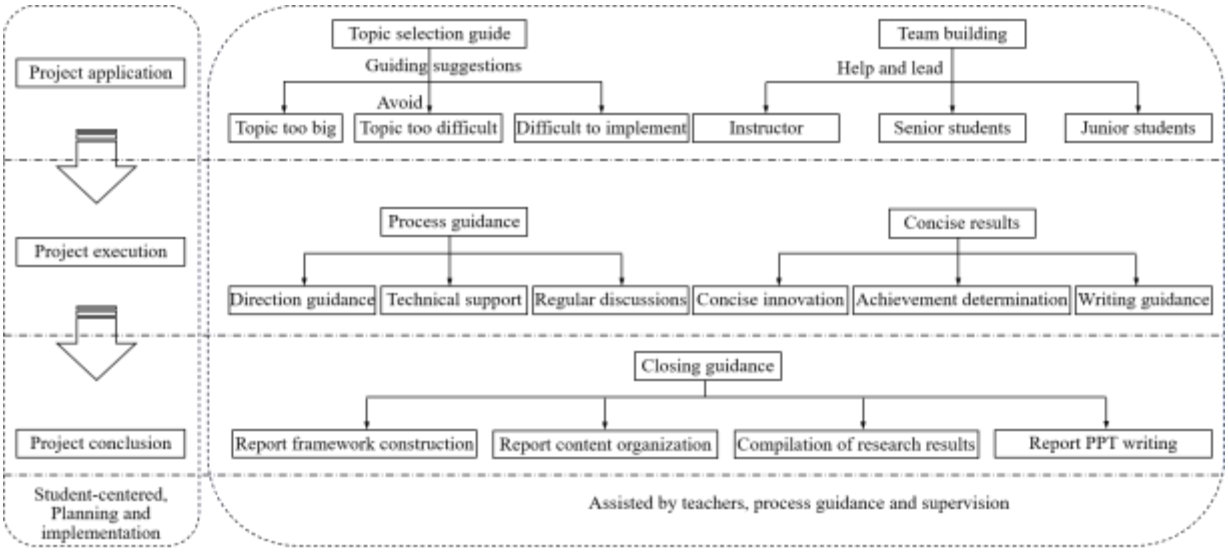


Fig. 12 Guidance System of Innovation and Entrepreneurship Training Program

Construction of "Scientific Research Project" Platform and Its Guidance System

The "Scientific Research Project" platform is mainly for students who have performed well in competitions and mass entrepreneurship and innovation programs, and have enough energy to learn. These students can combine their own scientific research expertise to integrate into the teacher's scientific research team, and realize the cultivation of rigorous scientific research thinking and scientific research literacy driven by teachers' scientific research projects, thereby further improving their own scientific research ability and innovation awareness. Our school encourages teachers to refine their government and enterprise projects, and open them to college students for selection and implementation. After more than five years of continuous exploration and practice, a self-owned scientific research training guidance system has been formed for our college students, as shown in Fig. 13.

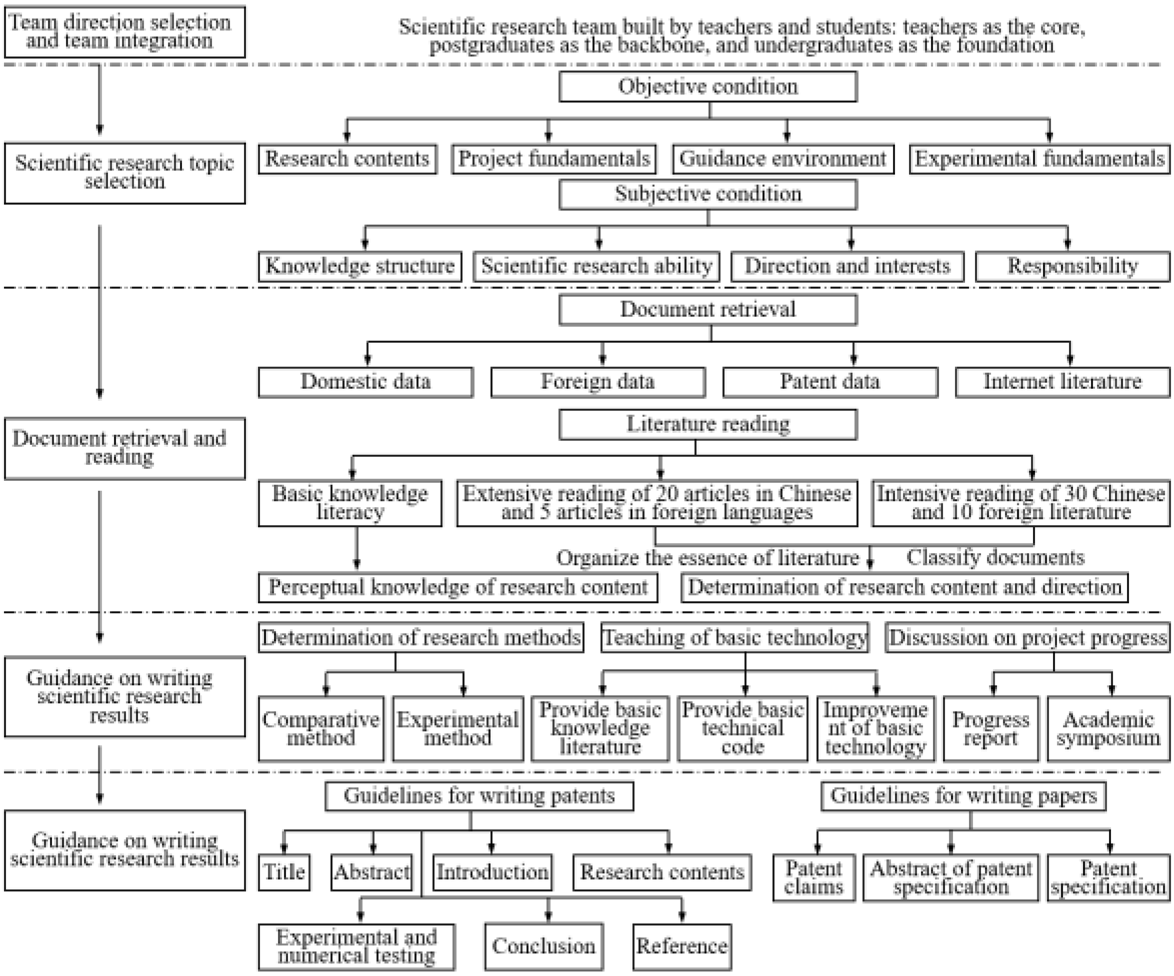


Fig. 13. Guidance system for scientific research projects

VI. CONCLUSIONS

In order to effectively improve the core abilities of applied mechanical majors, the project team independently carried out the construction of relevant teaching resources and training systems. Through the practical application of relevant teaching reform achievements in the training of mechanical majors, the following conclusions can be drawn:

(1) The engineering case resources for relevant courses completed around the three core course groups of "Mechanical Design", "Electrical Control" and "Electronic Control" not only stimulate students' interest in learning, but also effectively help them understand, master and apply course knowledge points.

(2) The innovative practice package for SCM control projects and the virtual assembly training platform for mechanical innovative design, which are independently developed around the students' professional core abilities, not only effectively help mechanical students apply course knowledge, but also strengthen their practical abilities.

(3) The constructed extracurricular innovation practice training system and related guidance system for college students not only enhances their comprehensive application of professional knowledge and problem-solving abilities, but also cultivates their innovation awareness and ability.

Over the past five years since the implementation of the project, students have been guided to participate in 11 provincial-level and above scientific and technological competitions, and have won a total of 258 provincial-level and above awards, including 63 provincial-level and above first prizes, with over 720 winners. Students are guided to publish 32 scientific research papers as the first author, including 1 paper indexed by SCI and 9 Peking University Chinese core papers. Students are guided to participate in applying for a total of 48 invention patents. Students are guided to participate in 58 innovation and entrepreneurship plan projects, including 31 provincial-level projects. Students are guided to participate in 43 various scientific research projects from teachers. The above achievements indicate that the quality of talent training in applied mechanical majors in our school has been effectively improved.

VII. ACKNOWLEDGEMENTS

This work is supported by the Jiangsu Province Education Science "14th Five-Year" Plan project (No. B/2021/01/03); Jiangsu Higher Education Association "14th Five-Year" Higher Education Scientific Research Planning Project (No. YB079); Jiangsu University of Science and Technology Undergraduate Education Teaching Reform Research Project (No. XJG2022059); The Ministry of Education's Industry School Cooperation Collaborative Education Project (No.202101124007, 221001388110505, 221002532133017); Jiangsu University of Science and Technology Zhangjiagang Campus 2022 "Golden Class" Cultivation Project (No. ZJG20221102).

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