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Practical Research on Promoting The Construction of New Engineering Education through Discipline Competition by PDCA Cycle

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Abstract. At the beginning of the emergence of the concept of new engineering, its connotation interpretation and paradigm change theme have become the focus of attention. The new engineering should not only pay attention to the construction of new industries and new specialties under the new technology, but also pay attention to the continuous training effect of talents under the new engineering education. Discipline competition is an effective way to cultivate the innovation and entrepreneurship ability of college students and improve their comprehensive quality. In order to promote the sustainable and good construction of new engineering education in Colleges and universities, this paper uses PDCA cycle as a means to integrate multi-disciplinary technology through discipline competition, promote the ability of college students to solve complex engineering problems, and thus improve the teaching quality of new engineering. Practice has proved that PDCA is applied to discipline competition in a circular way, providing a feasible path for the implementation of new engineering. After three years of tracking assessment on three different classes of computer science, the graduation design score has been raised from about 82 points to about 85 points, and the students' theoretical level, practical ability, innovation ability and discipline competition design level have been significantly improved.

Keywords: PDCA, new engineering, discipline competition, teaching quality

1 Introduction

Today's world is experiencing great changes that have not been seen in a century. A new round of scientific and technological revolution and industrial transformation are accelerating their evolution. The emerging new technologies, new business forms and new models put forward higher requirements for higher education. Since the outbreak of the epidemic, the global industrial chain, value chain and supply chain have been greatly affected, and the real economy has been hit unprecedentedly. Relying on the implementation of "new infrastructure" such as 5G, big data and artificial intelligence, the industry is accelerating its transformation to digitalization and intelligence. This has not only given birth to a number of strategic emerging industries and future industries such as digital economy, life and health, and new materials, but also driven the transformation and upgrading of traditional industries. At present, the contradiction between industrial development and the "lag" of innovative talent training in Colleges and universities is increasingly prominent. The era of great change calls for structural reform on the supply side of innovative talent training. The education system must have the wisdom to change, the way to respond, the courage to change, and take the initiative to respond to the new needs of the rapid economic and social development for the cultivation of innovative talents. When measuring innovative talents, we will make interdisciplinary thinking ability, cross-border integration ability, global competence, etc. the core qualities of innovative talents training [1].

At present, we are in the great transformation of the fourth industrial revolution. The fourth industrial revolution is mainly marked by artificial intelligence, virtual reality, clean energy and biotechnology. Industrial digitalization and digital industrialization have become the new normal. A new round of scientific and technolog-

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ical revolution and industrial transformation, especially the information revolution and energy revolution, have brought severe challenges to the cultivation of Applied Innovative Talents worldwide [2]. From the perspective of the world, the cultivation of Applied Innovation Talents faces some common problems, such as the cross integration of disciplines, the contradiction between production and education, and the definition of the core qualities of future engineers. In the face of these common challenges, world-class universities are launching reform and innovation plans for engineering education and paying more attention to the cultivation of innovative talents. For example, China's "new engineering construction", the Neet (new engineering education transformation plan) of the Massachusetts Institute of technology, and the CNE (creating future education action, 2018) of the Georgia Institute of technology. Taking China's new engineering construction as an example, the new engineering led the continuous iterative upgrading of the "excellent engineer education and training plan", made important progress in the new engineering construction, and made historic achievements in the innovation talent training reform [3].

However, there are still some problems to be solved in the current construction of new engineering, which are mainly reflected in the quality of talent training, the depth of integration of production and education, and the evaluation mechanism of teacher education, which are also common problems in the training of applied innovative talents. Although people adopt new teaching methods to promote the improvement of teaching quality, especially in higher education, the research on this topic has limitations. There are studies on improving teaching quality through stea [4-5], Yang et al. [6] supplemented teaching methods through online education mode, and Arif et al. [7] summarized many teaching experiences through improving online teaching methods. Marques et al. [8] promote students' learning through new methods such as mobile devices and augmented reality (AR). The concept of Gamification teaching has also been widely adopted by researchers from different fields and research fields [9], such as science, engineering, health, environment, sustainability and others [10-13]. Lin et al. [14] designed a new framework through sustainable artificial intelligence teaching. Although the above have achieved certain teaching results, the relevant research on the construction of new engineering and talent training through sustainable improvement is relatively few. PDCA cycle method is a process method for quality management and continuous improvement. Stoyanova et al. [15] have studied the application of PDCA to food safety management. Similarly, PDCA cycle can also be applied to improve the quality of talent education and training.

This paper first analyzes the capability framework of new engineering talents, and proposes that new engineering talents should have three characteristics: strong adaptability, high innovation and deep integration. Secondly, in order to realize and promote the construction of new engineering talents, PDCA cycle is proposed to achieve this goal through discipline competition. Third, through the comparison of teaching practice in artificial intelligence major for many years, students' theoretical level, practical ability and discipline competition design level have been greatly improved, which proves that PDCA cycle is an effective way through discipline competition and provides a feasible path for the construction of new engineering. Finally, summarize the full text and put forward the problems to be solved in the future.

2 Ability Framework of New Engineering Talents

2.1 New Engineering Paradigm and Characteristics

At the central talent work conference of China, it was stressed that a large number of outstanding engineers should be trained, and efforts should be made to build a team of engineers who love the party and serve the country, are dedicated, have outstanding technological innovation capabilities, and are good at solving complex engineering problems. Colleges and universities should deepen the reform of engineering education, increase the training of science and engineering talents, and explore and implement an effective mechanism for colleges and enterprises to jointly train high-quality composite engineering talents. The major strategic consulting project of "Research on engineering education governance system under great changes" of the Chinese Academy of engineering is to carry out consulting research with the theme of "promoting the modernization of engineering education governance system and cultivating a large number of excellent engineers". It is a positive response to the series of important requirements of the general secretary on the training of excellent engineers and a concrete practice to implement the spirit of the central talent work conference. Since the emergence of the new concept of engineering, its connotation and paradigm have become the focus of attention.

The new engineering paradigm includes three aspects: 1) technical paradigm, 2) scientific paradigm, and 3) engineering paradigm. On the one hand, based on the dynamic development perspective of engineering, engineering education [16-18] has been in a state of continuous development. New engineering should not only pay attention to the construction of new industries and new majors under new technologies, but also pay attention to the upgrading and transformation of traditional industries and old majors; On the other hand, based on the perspective of talent demand, new engineering originates from the new demand of new industries and new social forms. In the future, the demand for talent types will be very broad, and more emphasis will be placed on talents in different fields, different levels and different abilities. The new engineering should cover all aspects of talent demand from emerging to traditional industries, from large multinational groups to small, medium and micro enterprises.

At present, engineering education is still deeply influenced by scientific paradigm and technological paradigm. It should return to the track of taking practice, design and integration as the core, so as to reflect the characteristics of new engineering education [19-21]. As shown in Fig. 1, by defining three paradigms of new engineering: “technical paradigm, scientific paradigm and engineering paradigm”, from the perspective of technological progress and industrial development, the demand for talents in new engineering should show the characteristics of “integration, integration, Innovation, sharing and intelligence”. Finally, the market demand promotes the new engineering paradigm to show three main characteristics of “strong adaptability, high innovation and deep integration”, which has important guiding significance for the talent training and ability framework construction of new engineering.

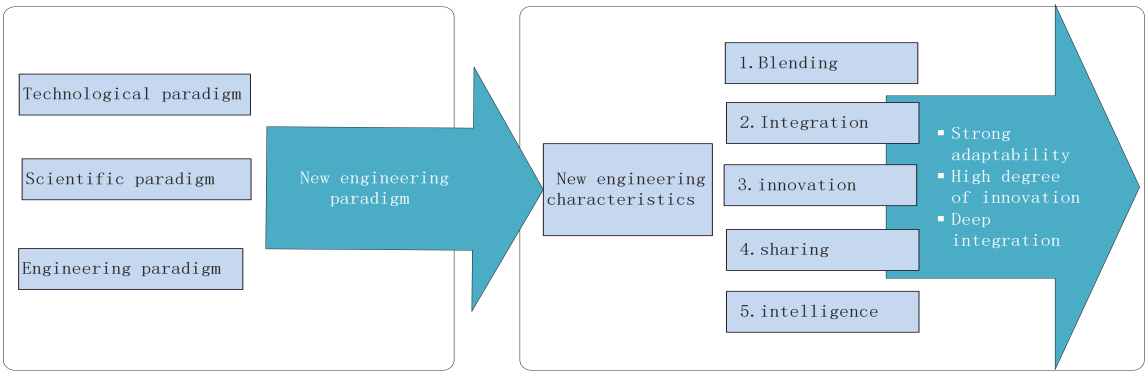

Fig. 1. Analysis of characteristics of new engineering

2.2 New Engineering Talent Capability Framework for Future

The construction of the engineering talent capability framework needs to be based on the engineering talent training goal, and the talent training goal should be oriented by the industrial and social needs to cultivate talents who can adapt to and even lead the future engineering needs [22-23]. Talent demand can be put forward from two perspectives:

1) From the industrial perspective. In the new economy of the Internet era, industries are rapidly integrating, and it is necessary to build a system that combines in class learning and extracurricular practice to train professional and technical talents who can adapt to industrial development, build “Internet+” cross-border composite talents with atmosphere building, talent incubation and achievement projects as the core, and build a real problem-oriented system to train basic research talents who can lead industrial development.

2) From a professional perspective. The key content of training different types of talents is to clearly define the ability composition of Engineering Talents: that is, the ability of “specialized” and “general”. “Specialized” refers to the professional ability. Due to the different specific industries and technology types in the future society, the demand for new engineering talents is different, which also requires that in order to meet the development requirements of the new economy and new industry in the future, it is necessary to cultivate new engineering talents with different professional abilities and establish a more personalized and professional engineering education and training mode; While “knowledge” refers to the knowledge and ability of other relevant aspects.

Professional ability is the stepping stone, but it also requires talents to be able to cope with complex and diverse social environment and practical problems. It is not enough to have professional ability, but also need to have diversified and integrated ability.

Based on the above, we can reconstruct the ability framework of new engineering talents facing the future from three dimensions: 1) individual ability, 2) team ability, and 3) overall awareness. Specifically, personal ability refers to the knowledge, skills and qualities that individuals possess, including the ability to learn and apply knowledge, the ability to think, judge and analyze, the ability to design and practice engineering, and the ability to create and innovate; Team ability refers to the ability that individuals show when working with others in the team, including expression and communication ability, team cooperation ability, emotion control and management ability, etc. global consciousness includes interdisciplinary thinking ability, cross-border integration ability, global vision, leadership, systematic thinking ability, etc., as shown in Fig. 2.

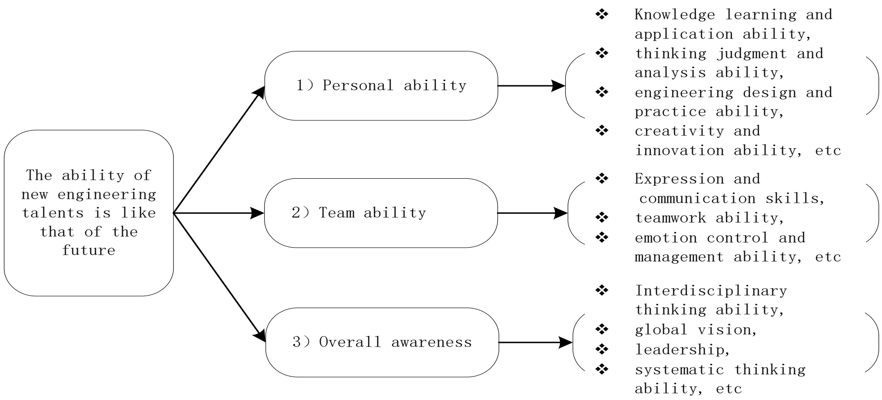

Fig. 2. Ability framework of new engineering talents facing the future

3 Promote The Construction of New Engineering with PDCA Cycle

The ability framework of new engineering talents facing the future mainly focuses on the cultivation of ability. The goal of new engineering education is to cultivate compound talents with theoretical knowledge level, practical design ability, expression and communication ability, team cooperation ability and comprehensive application ability. Discipline competition is an effective way to cultivate compound talents with comprehensive application ability. PDCA can promote the improvement of discipline competition level and promote the construction of new engineering. The schematic diagram of PDCA cycle acting on discipline competition to promote the construction of new engineering is shown in Fig. 3.

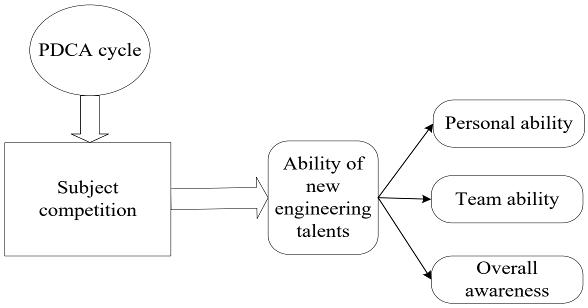

Fig. 3. Promoting the construction of new engineering education by PDCA cycle

3.1 Basic Theory of PDCA Cycle

PDCA is a universal model in management. It was first conceived by Hugh Hart in 1930, and was later rediscovered by Dr. Deming, an American quality management expert, in 1950. It was widely publicized and applied to the process of continuous improvement of product quality, so it is also called Deming Huan. The thought foundation and method basis of total quality management (TQM) is PDCA cycle. PDCA cycle method divides quality management into four stages [24-25]: plan, do, check and act. These four stages do not end with only one run, but operate continuously. Each time, part of the problems are solved, and the problems that have not been solved are transferred to the next cycle. The quality of the operation results is gradually rising, as shown in Fig. 4. Therefore, PDCA cycle method is regarded as the basic method of quality management and quality improvement.

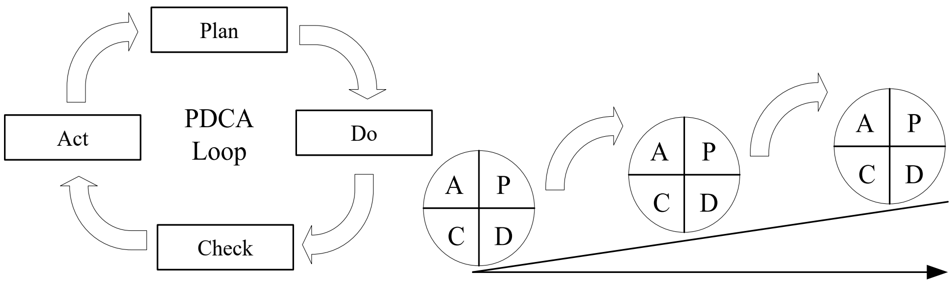

Fig. 4. Schematic diagram of PDCA cycle principle

3.2 Application of PDCA Cycle Method in Discipline Competition

Discipline competition is an effective way to cultivate college students' innovation and entrepreneurship ability and improve their comprehensive quality. PDCA cycle, as a basic method of quality management, is applied to discipline competition design, which is very helpful to improve the quality of discipline competition. Now take the discipline competition of computer science and technology major of new engineering as an example. In the discipline competition design, there are a lot of design processes such as design, programming, review, testing, modification, retest and modification. This process is a process of continuous improvement and is applicable to PDCA cycle method. The PDCA cycle can be divided into four stages: 1) the target plan (P) that the discipline competition design work should achieve; 2) Implementation of discipline competition design (d); 3) Review of discipline competition work (C); 4) Summary and improvement of discipline competition design (A). Each stage of PDCA cycle can form one or more "sub" PDCA cycles, and the whole constitutes an organic and continuously improving system. The PDCA process of discipline competition design is shown in Table 1.

Table 1. PDCA management process of discipline competition

PDCA	Management process of discipline competition
Plan	P1: Determine the discipline competition items
	P2: Requirements for discipline competition
	P3: discipline selection of discipline Competition
	P4: Discipline competition team building (students and instructors)
	P5: Assignment issued by the instructor
	P6: Students write the opening report

Do	D1: Search relevant domestic and foreign literature D2: Preliminary scheme design D3: hardware design D4: Software and interface design D5: Database design D6: System test
Check	C1: Design document review C2: Test document review C3: System display review C4: Code review C5: System completeness review C6: Expert review
Act	A1: Entry score A2: Expert feedback A3: Comparison of peer works A4: Competition summary report A5: Document sorting and archiving A6: Exhibition of competition works (reference and basis for the next competition)

The PDCA process of discipline competition design is a continuous cycle, and its schematic diagram is shown in Fig. 5. Discipline competition is a complete PDCA cycle from the selection of participating projects to the completion and preservation of works. The work results of the last step can be used as a reference for the PDCA improvement and promotion of the next competition. At the same time, each node can also be a "sub" PDCA process. Based on this, the whole process constitutes an organic and constantly improving system, which provides a strong guarantee for the training and promotion of new engineering talents.

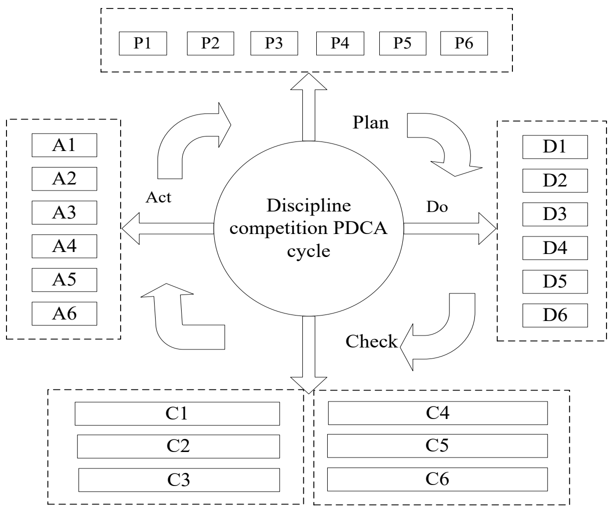

Fig. 5. Discipline competition PDCA cycle diagram

Establishment of Competition Project Achievement Objectives (P). This stage is the planning stage, and it is the premise to ensure the quality of discipline competition design to formulate the target standards of discipline competition design. As shown in Fig. 5, there are mainly six stages in this stage, which are defined as P1-P6. 1) The entry items of the discipline competition, 2) the entry requirements of the discipline competition, 3) the discipline selection of the discipline competition, 4) the construction of the discipline competition team (students and instructors), 5) the design assignment issued by the instructors, and 6) the students write the opening report. "A good start is half the success". A good goal planning is the premise of producing excellent discipline competition design. The quality standard is the reference for the quality of each work. Therefore, PCDA cycle is suitable for the quality design standard of discipline competition, and P is the premise, standard and requirement.

Implementation of Competition Project Design (D). This stage is the execution stage, which is the core of PDCA cycle and also a stage with a large workload. It needs division of labor and cooperation. As shown in Fig. 5, there are mainly six stages, defined as D1-D6. 1) To search for relevant domestic and foreign literature, to do a project or design a work, you need to query relevant domestic and foreign literature, so as to learn from and reference relevant materials; 2) Preliminary scheme design: preliminary design of hardware, software and communication interconnection scheme; 3) For hardware design, it is necessary to make schematic diagrams, select single-chip chips and simulation tools, and simulate, debug and program single-chip computers; 4) In software and interface design, mastering the programming language is a very important link in designing intelligent products. To achieve a certain function, different languages are used, and complex programs are different. GUI is the interface of human-computer interaction and the key to the friendliness of product design; 5) Database design Almost all software systems need to use databases. Planning and designing databases and data dictionaries is an important part of software products; 6) System test: unit and integration test shall be carried out for the implementation of each system. What needs to be completed in the execution stage. If there is something wrong with the test, a new PDCA process shall be completed.

Check of Competition Results (C). This stage is the inspection stage, which mainly reviews and reviews the project results, including the results and documents. It is mainly divided into six aspects, defined as C1-C6. 1) Review the design documents to see whether the results meet the technical requirements; 2) Review test documents to see whether unit test, fusion test and acceptance test are conducted; 3) Review the display of system works to see whether the GUI interface is friendly and meets the design requirements; 4) Review the code to see whether the flow chart of the program and the normalization of the code meet the requirements; 5) Review the completeness of the system to see if the system has security holes, whether it is vulnerable to network security attacks, and whether there is information leakage; 6) Local and external audit experts are invited to conduct review. This part is a very important process. If there is any imperfection, a new PDCA process needs to be completed.

Competition and Promotion of Competition Items (A). This stage is the processing stage. In the whole process of the discipline competition, it is a link to participate in the competition. The competition results reflect the quality, innovation, novelty and usability of the work. It is mainly divided into six aspects, defined as: A1-A6. 1) The evaluation of the entries can reflect the quality of the entries through the evaluation of the entries by experts. At the same time, the students' ability to show and explain the works is also exercised; 2) Expert feedback, which can greatly help the improvement of works; 3) Compared with peer works, students may see other works through the competition, and can see the gap, which is also very helpful to the improvement of works; 4) The competition summary report can always reflect its own strengths and weaknesses through the preparation of the competition summary report for further improvement; 5) Document sorting and archiving: the sorting and archiving of documents is an important part of the design work and the basis for further improvement; 6) The results of the competition works should be displayed, and the excellent works should be preserved. On the one hand, the results should be displayed, and on the other hand, it will play a very important role in cultivating the learning interest of the next generation of students. This process provides a basis for the next PDCA cycle.

4 Comparison of Practical Effects

4.1 Selection of Competition Items

The new engineering computer science and technology discipline competition is divided into three categories: the first category is national, the second category is provincial, the third category is school level. There are four major competition events, such as four typical events (for convenience of expression, the projects are not limited to four): 1) computer design competition, 2) Internet of things competition, 3) "Internet+" competition, and 4) “challenge cup” competition. Each event is continuously improved through PDCA cycle. The classification chart of the new engineering discipline competition is shown in Fig. 6. Students first select three types of school level competition projects, and through PDCA cycle, advance to class II provincial competition projects, and then through PDCA cycle, advance to class I national competition projects.

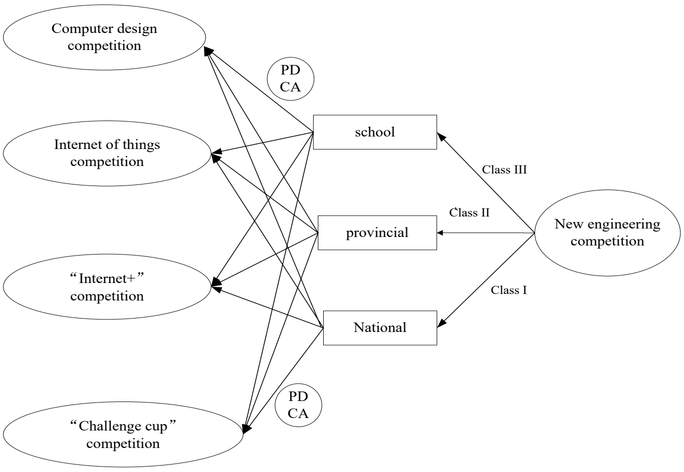

Fig. 6. Classification diagram of new engineering competition

4.2 Comparison and Analysis of Implementation Effect

This study selects undergraduates from the College of information engineering as the research object. There are 35 students in each of the three classes of computer science and technology major in the new engineering, including 60 boys and 45 girls. In the study, three groups were divided for research and comparison: a) Ordinary class, represented by a, this class carries out normal experiments and teaching; b) Experimental class, represented by B, this class adds comprehensive experiments and competitions; c) PDCA competition class, represented by C, is driven by discipline competition through PDCA. The assessment is conducted from four dimensions: 1) mastery of theoretical knowledge, passing the assessment and scoring; 2) Mastering practical knowledge and scoring through courses; 3) Discipline competition, the number of awards (mainly the results of category 1 and category 2 competitions); 4) Graduation design, through graduation defense score. After three years of follow-up assessment (four years for undergraduate university, one year for basic courses and three years for professional courses), the final comparison of the assessment results of the new engineering computer specialty is shown in Table 2.

Table 2. Mobile internet assessment comparison table

Appraisal dimension	Ordinary class (A)	Experimental class (B)	PDCA competition class (C)
1) Theoretical Score	80.8	82.3	84.6
2) Practical Score	75.2	83.9	86.5
3) Number of awards in competition	4	13	25
4) Graduation Score	81.4	82.5	85.2

As shown in Fig. 7, it can be seen that the examination results are positively related to the number of competitions, that is, the academic competition promotes the improvement of students’ theoretical and practical level, and the comprehensive ability is also effectively improved.

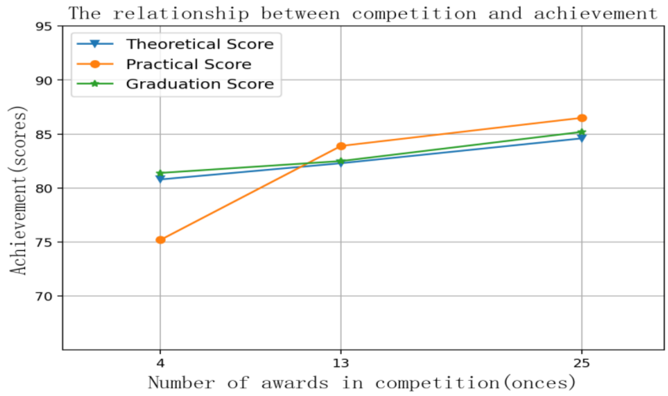

Fig. 7. Mobile Internet assessment comparison histogram

Table 2 is drawn into a horizontal histogram as shown in Fig. 8. It can be seen that the teaching effect has been significantly improved from theoretical knowledge to practical ability. From Class A, class B and class C, the graduation design score has increased from 81.4 and 82.5 to 85.2, which fully shows that the teaching effect of new engineering driven by PDCA has been greatly improved.

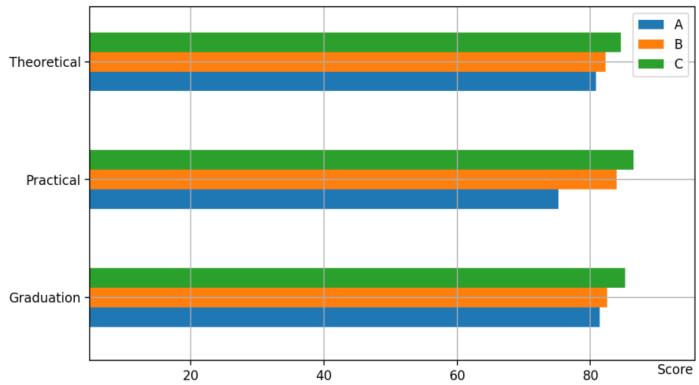

Fig. 8. Mobile Internet assessment comparison histogram

4.3 Realization Effect of Competition Items

The competition items listed above: computer design competition, Internet of things competition, “Internet+” competition and “Challenge Cup” are all team competitions, which need to form a team of 3 to 4 people. Therefore, personal ability, team cooperation ability and overall system perspective are required. Through the promotion of PDCA, we have summarized the following five achievements: (taking an intelligent project - cloud platform based environmental monitoring system as an example).

(1) Improvement of document capability. Students can learn the design method of software engineering by writing the opening report, summary design, detailed design, test report and other documents (such as CO2, temperature, humidity, PM2.5, methanol, etc.), improve the ability of text expression, and learn the editing ability of document format, table and flow chart.

(2) Improvement of hardware design level. Students can learn the simulation and debugging skills of single-chip microcomputer through demand analysis, querying relevant literature and sensor data, making schematic diagrams, selecting single-chip microcomputer chips and simulation tools.

(3) Improvement of software design level. Students need to master the programming language Java, learn web framework, database, data interface, GUI design, multi-threaded programming, mobile app design, etc. through the design scheme.

(4) Mastering cloud platform mobile Internet knowledge. Students need to learn cloud platform deployment, master modbus, mqtt and other communication protocols, and master data analysis and CRC verification of communication protocols.

(5) Accumulation of team work experience. Learned to communicate and exchange with teachers and team members. Through the practice of the competition, the ability of the project team to organize and cooperate has been trained, and a lot of project process experience has been accumulated.

5 Conclusion and Future

Through the analysis of the reality of the new round of scientific and technological revolution and industrial revolution, this paper first discusses the theoretical significance and practical value of new engineering, and then proposes to achieve this goal by PDCA cycle and discipline competition in order to realize and promote the sustainable talent construction of new engineering; Through many years of teaching practice in computer science and technology majors of new engineering, students' theoretical level, practical ability and graduation project level have been greatly improved, which proves that PDCA cycle is an effective way through discipline competition and provides a feasible path for the construction of new engineering, Make the new engineering education concept and initiative, which originally originated from practice, truly become a plan that can be implemented and can solve the existing problems of China's engineering education, and make the new engineering truly move from "practice" to practice.

Since this study is aimed at the computer science and technology major of new engineering, whether it can be applied to other majors needs further research. Promotion and research in other specialties are issues to be considered in the future.

6 Acknowledgement

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