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Effectiveness and Evaluation of Online and Offline Blended Learning for an Electronic Design Practical Training Course

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ABSTRACT

It is imperative to bridge the disparity between college students' practical capabilities and professional expectations. To help facilitate such a progression, an electronic engineering course oriented around the Creative Innovation Practice project has been designed with the objectives of student-centric instruction, integration of both theoretical and practical components, and application of knowledge through project case studies. Adopting the open engineering education approach, there has been an initiation of project-driven blended teaching centered on "constructivism," constituting a model that joins online and offline instruction, in-class and out-of-class tasks, activities inside and outside the laboratory, coursework, and contests. This amalgamated mode of learning has had a beneficial outcome in enhancing learners' self-learning capabilities, hands-on practice, as well as their inventive aptitude. According to an analytic hierarchy process (AHP) evaluation and assessment, blended teaching could effectively augment participants' eagerness to learn and motivation.

KEYWORDS

AHP, Blended Learning, Evaluation Analysis, Practical Training Course

INTRODUCTION

In the past ten years, with the rapid advancement of technological innovation, industrial upgrading, and the informatization of Chinese enterprises, the demand for high-tech personnel has effectively promoted the rapid development of related majors in higher education. After graduation, students can work as senior technical or management personnel in enterprises, but student quality and ability development are inconsistent, which cannot meet society's demand for talent. According to the recent feedback from Shandong Technology and Business University (SDTBU) on the recruitment of graduates, "poor practical application skills" account for 39.41%, which is the important reason for their dissatisfaction, as shown in Figure 1. One possible reason is that students who may be affected by the epidemic are deprived of possible chances of entering the enterprise. Therefore, motivating students to partake in experiential learning within a professional setting is paramount in the foreseeable future. This requirement stems from the fact that inadequacies in practical aptitudes are symptomatic of a deficiency in university education in terms of the design, teaching methods and practice of relevant courses. There is consequently an urgent need for further refinement of practical training in universities.

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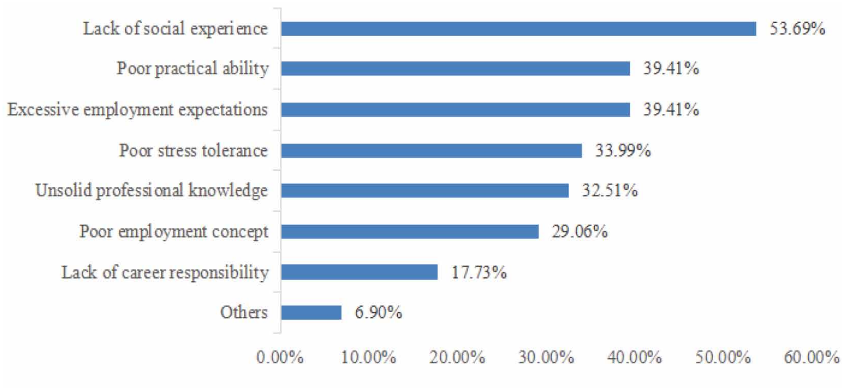
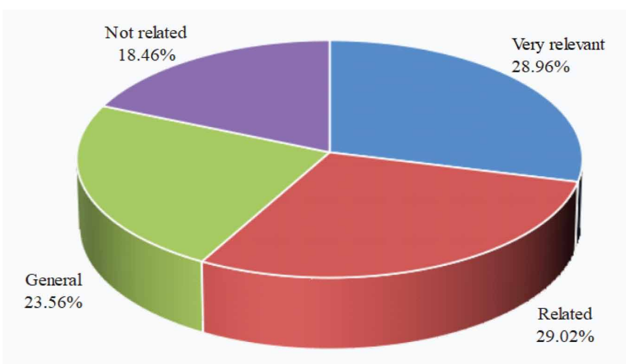
Figure 1. Employers' Feedback on the Shortcomings of Graduates when Applying for a Job



Moreover, taking the matching rate of employment and major in graduates of SDTBU in the past three years as an example, from 2019 to 2021, the matching rate is not high, as shown in Figure 2. There are some possible reasons behind. Firstly, students cannot find jobs corresponding to their major. Secondly, according to the feedback on the graduate's ability from employers, the theoretical knowledge of graduates is disconnected from the practice, and the graduates cannot quickly adapt to the working environment. Obviously, it is quite unusual that the employment situation of students is good, but the quality of employment is not high and needs to be improved. The main reason is the lack of students' professional employability, especially practical innovation ability, and the lack of in-depth learning and exploration of professionals and occupations.

Figure 2. The Professional Matching Situation of the Graduates' Current Job



It has become an important task facing higher education to cultivate industrial and technical talents with innovative spirit and strong practical ability, and also an urgent task for colleges and universities to train engineering talents (Liu, 2011; Wu et al., 2017). Therefore, taking economic development needs as a booster for students' career development, practical innovation, and engineering ability should be considered as the core to build students' employment quality for the engineering major, which will further improve the employment quality of college students.

Currently, according to the characteristics of engineering teaching in the process of talent training, there are some problems inside. One reason is that the ability training mode of practical teaching has been unclear for a long time (Wang, 2020; Xiang et al., 2021). Because the previous course program cannot adapt to modern enterprises, the traditional teaching mode cannot take advantage of modern teaching techniques and resources, and it is difficult to break through the limitations of laboratory time and space, thus leading to the lack of students' cognition and active consciousness. Another reason is that the effect of the in-campus practice is not satisfactory (Peng & Chen, 2021; Ding et al., 2022). The teaching process's simple, verified practice content accounts for the main part. Furthermore, with the higher and higher integration of experimental instruments, students' hands-on ability is not strengthened but weakened, and students' practical innovation ability cannot keep up with the development of industrial enterprises.

Solving these problems requires a change in the existing teaching mode. We should integrate theories with practice based on engineering education theory, and hands-on operation must be combined with engineering practice. To sum up, it emphasizes the whole process of engineering project practice. By eliminating verification experiments and adopting design-based comprehensive project experiments, students can acquire practical skills and comprehensive innovation in project production based on constructivism and student-centeredness.

Starting from the curriculum reform of "Creative Innovation Practice (CIP)," this paper studies the reform of practical training courses under engineering education through the electronic design and production of project-driven experimental teaching. We have designed the project production process as an online course and guided students to use the online course to learn and to do their electronic projects, trying to combine online and offline blended teaching, breaking the time and space constraints of the practical aspects, effectively improving the teaching and learning efficiency of the practical training courses. At the same time, by designing an experimental pocket device, the open experimental environment is realized, which can not only complete the project production in the laboratory but also help students to take away the experimental equipment and use their spare time to realize the project production. Moreover, especially during the epidemic period, we can also realize the remote guidance of blended learning, which shows the beneficial attempt of this teaching method for practical teaching.

LITERATURE REVIEW

As a new teaching model, online education has the advantages of high efficiency, convenience, and real-time (Guo, 2021). In recent years, it has flourished in many universities. However, especially after 2020, due to COVID-19, normal offline teaching has been greatly impacted (Megahed & Ghoneim, 2022). To block the transmission of the virus, the Ministry of Education of China has issued 'suspending classes without stopping teaching and studying.' All universities actively prepared and carried out 'Cloud Classroom.' pushing the popularity of online teaching (Tambunan et al., 2021; Wang et al., 2022). However, most engineering majors need to conduct experimental practice courses. Students cannot return to school or come to the laboratory, and many practical courses are difficult to carry out because of the pandemic.

In recent years, online teaching methods such as Massive Open Online Courses (MOOC), Small Private Online Courses (SPOC), and flipped classrooms were introduced into practical blended teaching to help to develop and design experimental practical courses (He et al., 2015; Park, 2015; Wang et al. 2017; Chen & Meng, 2021). Blended learning combines the advantages of traditional learning methods with online learning. It not only supports the leading role of teachers in guiding, enlightening and monitoring the teaching process, but also fully mobilizes students' initiative, enthusiasm and creativity as the main body of the learning process. We can obtain the best learning effect if the two aspects complement each other.

Blended teaching focuses on the effectiveness of learning and emphasizes the multiple interactions between teachers and students, promoting individualized learning and the overall development of learners (He et al., 2015; Canessa & Logofatu, 2013). The teaching effect is directly reflected in the achievement of students' independent learning and scientific research, cooperation, and communication, which contributes to students' expansion of knowledge and thinking and improves scientific exploration ability.

The experimental practice course has the characteristics of interaction and practicality. Its interaction can be realized through online and offline blended learning, but the practicality is currently only suitable for some courses that can be remotely controlled, such as computer program language courses, which can be realized through the computer or online software programming (Barbosa, 2022). The courses of signal communication can be realized through network transmission, but they cannot completely replace offline courses (Wei et al., 2019; Liu & Yu, 2019). Most of them combine virtual and real, and online and offline laboratories. At present, the most popular is the virtual simulation experiments, which can be realized through the deep integration of information technology, intelligent technology, and experimental teaching to realize "online experiments" and "virtual reality experiments" (Dong et al., 2022; Hou et al., 2022). At present, it is widely used in experimental courses in mechanical engineering (Luo, 2022), architecture (Xu et al., 2022), chemical engineering (Fan et al., 2022), medical (Guo & Sun, 2022) and other majors (Li et al., 2022). In recent years, Chinese universities have been promoting such experimental courses, and the Ministry of Education of China has also launched a first-class "virtual simulation" course. However, due to the high cost, it is only carried out in a few experimental courses with the expensive experimental system, but it is a future development trend. Although many people are trying to remotely control the experimental course of hardware operation (Xu et al., 2020), it cannot be completely replaced, or the experimental effect cannot be comparable to the actual experimental scene, so most of them are just learning theory online, and they need to enter the laboratory offline for physical operation.

In 2017, we tried to set up a practice course that combined online and offline with the goal of 'inspiring and cultivating creative and innovative ability.' The online open course had been launched on the Chinese university MOOC and Zhihuishu platform. We have set up an open laboratory, where students can enter the laboratory at any time to complete the experiment. At the same time, it is equipped with pocket-sized lab equipment, so students can take it away and return to the dormitory or other learning places to study. We have tried to combine online and offline blended learning of experimental courses.

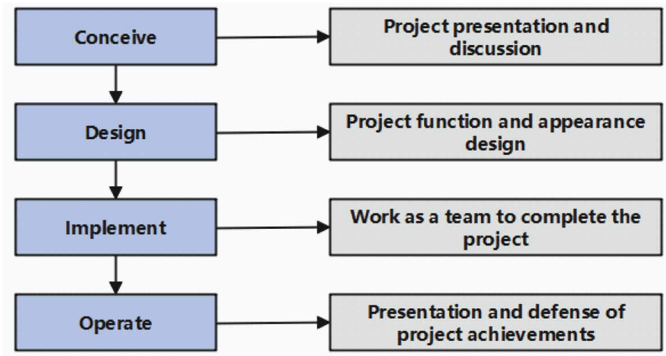
Therefore, after the epidemic, the students returned to school. Although many teaching activities have returned offline, online teaching convenience has also been deeply rooted in the minds of both learners and educators. Students can study and practice in any place with devices, which not only facilitates students' knowledge learning and practical operation, but also greatly expands students' practical time and space. Combining the advantages of teachers' traditional offline teaching and students' modern network learning, blended teaching can not only play the leading role of teachers in guiding, enlightening, and monitoring the teaching process, but also fully reflect the initiative, enthusiasm, and creativity of students as the main body of the learning process, which can well solve the existing problem. Considering its advantages, the combination of online and offline teaching greatly improves the learning effect of experimental teaching and has been rapidly promoted and applied.

THEORETICAL BASIS

CDIO Engineering Education Theory

CDIO is the abbreviation of 'conceive, design, implement, operate', an engineering education model initiated by the Massachusetts Institute of Technology and practiced by many universities around the world, as shown in Figure 3 (Crawley et al., 2007). CDIO engineering education mode is the product of the development of industrial engineering education and talent personnel training education. It pays attention to practical engineering problems, takes the CDIO of the engineering project as the

Figure 3. CDIO Engineering Education Concept



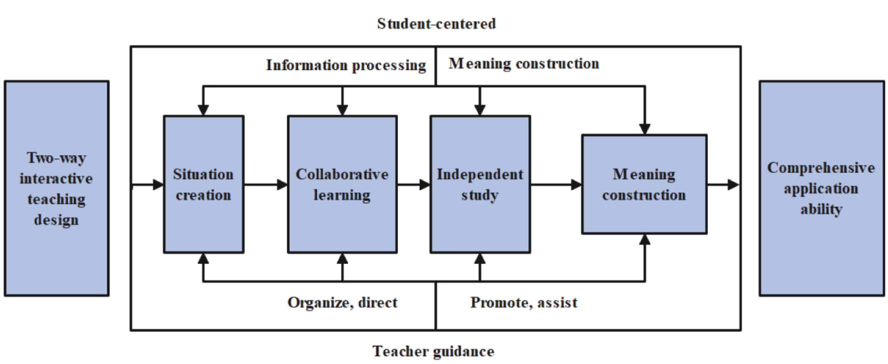
carrier, lets learners participate in the whole process, and finally designs their works. Combining Project-based task-driven, hands-on, and engineering practice, students' practical innovation ability is deeply cultivated. Its purpose is to solve the lack of engineering practice operation in traditional teaching, combine theory with practice, and improve students' comprehensive ability.

Learning Theory of Constructivism

Constructivism stems from the theory of child cognitive development proposed by Swiss psychologist Piaget (Steffe & Gale, 1995; Zhang & Sun). It believes that learners acquire knowledge independently, spontaneously, and actively. The role of teachers lies not in teaching but in helping and guiding learners to put forward motivational scenarios, and grow or construct new knowledge and experience from the actual knowledge and experience. Constructivism advocates learning in real-world situations, with learners as the center, using various heuristic teaching methods and means to stimulate learners' enthusiasm and intrinsic potential, continuously improving collaborative and independent learning abilities and helping students build their knowledge networks. We show the constructivism teaching model in Figure 4.

This paper will take CIDO engineering education theory as the goal orientation, and carry out project-driven learning based on 'Constructivism'. Through online and offline learning and open practice, students can finally realize the construction of knowledge, improve their integrated skills and enhance their problem-solving ability.

Figure 4. Teaching Model Under Constructivism



BLENDED TEACHING DESIGN

Course Characteristics

Build Students' Knowledge System and Cultivate Ability Through Practice

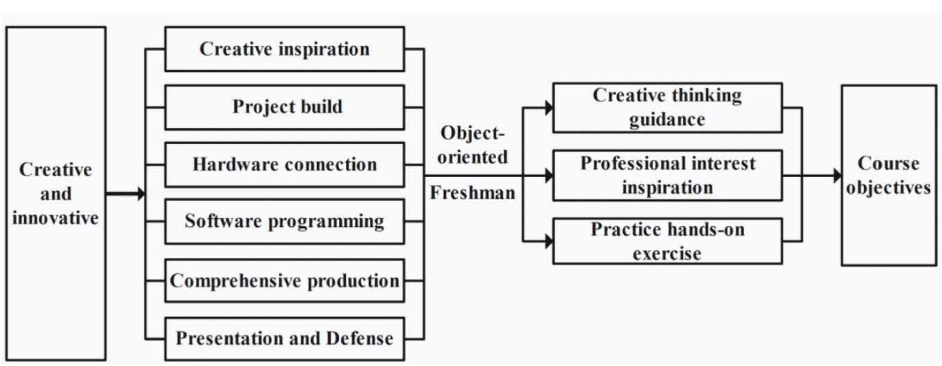
CIP course was initiated in 2013. This is an engineering education innovative course about electronic design training. After several years of practice, the project-based content design of the course has been gradually improved and optimized. This course has abandoned the teacher-centered teaching mode and established a project-based learning mode that is student-centered. It integrates knowledge into project cases in practice. Considering the rapid update of knowledge, we expand new knowledge and technology in the project practice. This will solve the drawbacks of the currently closed classroom lectures and establish the concept of open engineering talent personnel cultivation. Students gain proficiency through consistent application of the subject matter. To further foster greater understanding, we are developing a multi-faceted educational platform by integrating online and offline instruction within and beyond the traditional classroom and laboratory settings, combining courses with practical competitions. Through creative guidance and professional learning, practice in conducting projects and design, it guides students to participate in innovative scientific activities, and improves their comprehensive innovation ability.

CIP Course Structure

Project-Style Case Design

According to the needs of electronic engineering practice innovation, a project-driven curriculum is constructed, using blended teaching to integrate professional knowledge learning into the design and application of electronic production, and the Internet of Things (IoT) to improve students' hands-on ability and innovation ability in practice. Therefore, IoT achieves the purpose of inspiring interest and enhancing hands-on practice and professional learning. CIP focuses on project-based learning based on electronic engineering design, including creative inspiration, project construction, software and hardware programming, comprehensive production, display, and defense. Based on constructivism, project-driven teaching can build a real learning situation for students. Teaching is student-centered. Teachers stimulate students' learning enthusiasm and internal potential through guidance, improve students' group learning and collaboration ability, and help students build a knowledge system. The students' subjective initiative can be used for practical exploration by designing diverse project cases combined with online and offline learning. We show the course construction in Figure 5.

Figure 5. Project-driven Course Construction



The case project of CIP is built upon a software and hardware platform of Arduino, with the incorporation of professional knowledge in the production of projects that are made to create meaningful connections to life. These projects include colorful lights, warm beds, magic pianos, interactive pianos, smart potted plants, smart blinds, safety assistants, smart greenhouses, and more. Additionally, single-chip application expansion with C language programming is taken into consideration.

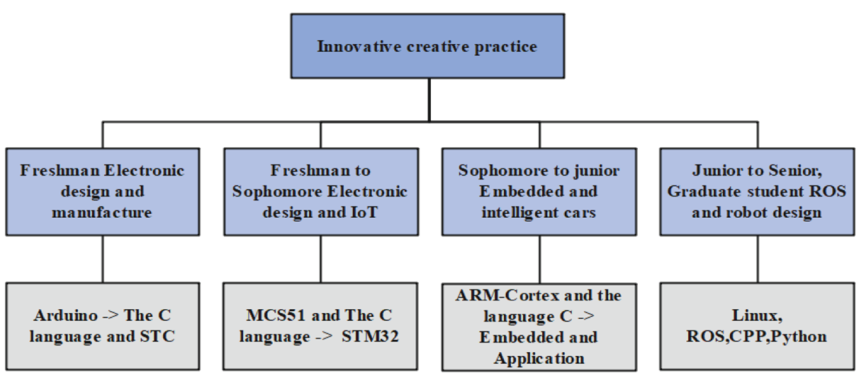
MOOC Design

Combining the characteristics of online learning, the principles of fragmentation, miniaturization, and simplification are applied in MOOC design, the knowledge involved in each project is reasonably divided, each lecture is subdivided into several subsections, and corresponding courseware and videos are produced for each subsection (The length of each video is 10~20min). The video includes elements such as the creative inspiration of the project, the use of components and sensors, the principle of electronic circuit design, software programming, hardware connection, appearance production, and function expansion. To promote learning, it carefully designs test questions including single choices, multiple choices, fill-in-the-blanks, and judgments, to test students' knowledge and skills mastery. It also designs several open classroom discussion questions for each part of the project, which can guide students to think actively and stimulate their desire for knowledge exploration and divergent thinking. The MOOC display content is the basic ideas and functions of project production, and students must expand at least 2-3 functional design points on this basis. This course is an experimental practice course, in which students must complete the design and exercise their practical skills in online learning and offline explanations.

Course Learning Mode

The course adopts blended teaching that combines online and offline learning, includes in and out of class, inside and outside the laboratory, and uses a pocket experiment kit to expand open experiments. Through the project-driven combination of teaching courses and competition to achieve the integration of specialization and innovation, the new course learning mode is applied, as shown in Figure 6.

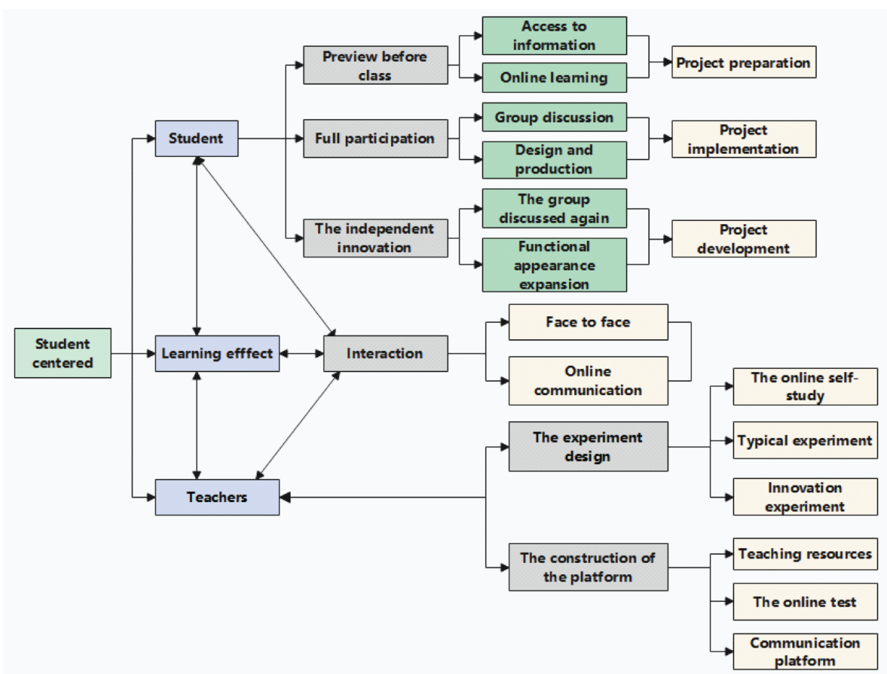
Figure 6. Course Development Form



Online and Offline Blended Teaching

After selecting courses on the MOOC platform, students can use the off-class time to study and discuss or directly ask the teachers online. Teachers can check the relevant information before class and answer students' questions during class. The online video includes creative guidance, knowledge explanation, programming realization, and hardware connection and production. Students can achieve self-learning and complete their projects. The offline experimental practice offers on-site guidance for creative inspiration, hands-on practice, and comprehensive production, encouraging students to expand functions independently, show defenses, write project reports, and analyze and summarize. Therefore, students will form a complete knowledge system and accomplish their training. Blended teaching puts students at the center of teaching activities, as shown in Figure 7, and pays attention to the achievement of the learning effect and the communication and interaction between teachers and students. From the perspective of the learner, the learning process is dominated by students for preparation before class (preparing for project implementation through data access and e-learning), participation in the whole process of class (project implementation through group discussion and design and production), and independent learning and innovation (function and appearance expansion through group discussion to complete project expansion). From the educator's perspective, the curriculum construction focuses on teachers for experimental project design and platform construction. Students and teachers can communicate and interact in person and through online network, platforms to address issues arising during the learning process and provide constructive feedback. By employing online learning and submitting project designs, an online platform ensures that educators can monitor student progress closely, allowing them to modify their teaching strategy for increased efficiency, optimize teaching content and foster a more engaging relationship with their learners. All aspects work together to continuously improve teaching methods, optimize teaching design and learning effect, and continuously improve student-centered blended practical teaching.

Figure 7. Student-centered Blended Experimental Practice Teaching

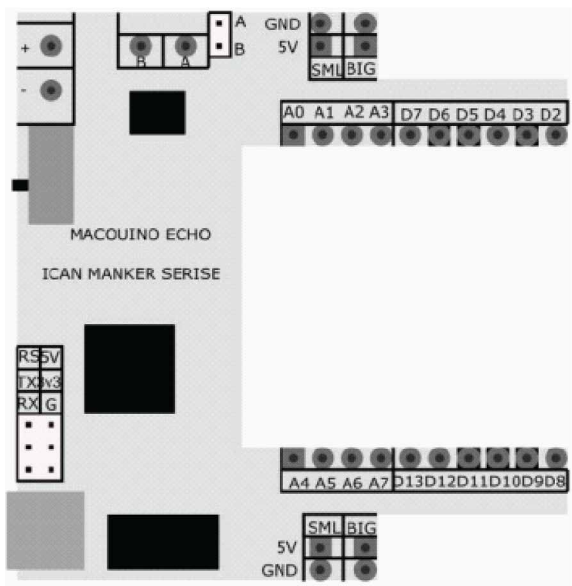


Open Experiment and Pocket Experiment Kits

We have established an open laboratory environment so students can learn and practice simultaneously during offline classes. In addition, the laboratory is open at any time, so students can go to the laboratory to complete course study and practical tasks according to their schedule.

In addition, the pieces of equipment involved in the course are all pocket experiment kits. A small and easy-to-use learning board Arduino is designed, as shown in Figure 8, the Arduino board has 5V and GND, digital interfaces D2 ~ D13, and analog interfaces A0 ~ A7, and its multiplexing interfaces are D3, D5, D6, D9, D10, and D11. The equipment is portable, and students can bring it anytime, for example, after returning to the dormitory. In addition, the USB interface provides power to equipment, thus broadening the scope of learning by allowing students to stay up-to-date outside of class hours and in their own laboratories. Consequently, this open practice teaching method transcends traditional boundaries, enabling a diversified form of instruction both inside and outside the classroom.

Figure 8. Arduino Learning Board



Blended Teaching - "Smart Blinds" Course Case Analysis

Firstly, some preparation must be finished, including completion of basic knowledge acquisition and online learning tasks and project design preparation before class. Secondly, the project design is completed in the offline class. Smart blinds design includes creative inspiration and guidance, brainstorming, mind mapping, sensor application, hardware and software design, appearance design, and functional expansion. It cultivates students' ability to discover, analyze and solve problems, and cultivates students' innovative thinking, professional knowledge, and innovative ability. We show its course procedures in Figure 9. Finally, students should complete the project training report and submit it to the MOOC platform after class.

Figure 9. Course Development Process

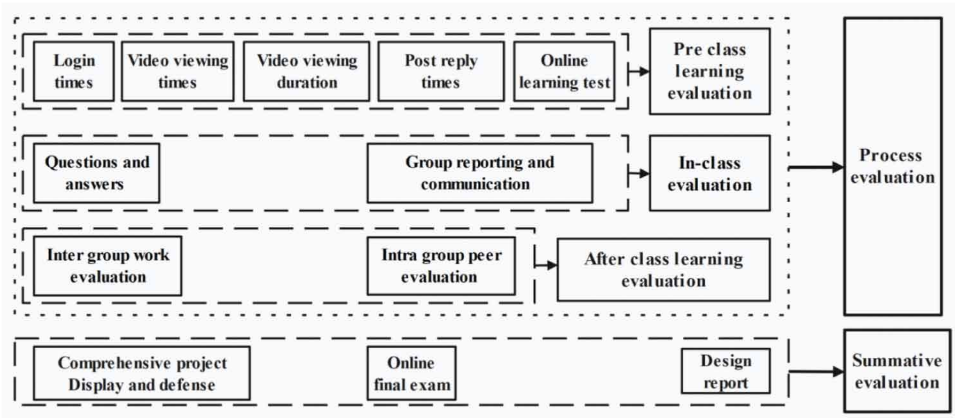
BLENDED TEACHING EVALUATION

CIP Course Blended Teaching Evaluation

To evaluate the effect of blended teaching, we should not only examine students' pre-class preparation, learning attitude, and knowledge mastery in class, but also examine students' practical and innovative abilities, problem-solving abilities, and many other capabilities (Li & Han, 2017; Zhang & Zhu, 2020). Utilizing a three-step method comprising of dynamic process assessment coupled with summative examination, the performance appraisal is centered around the entire learning procedure (evident in Figure 10), covering pre-class evaluation, classroom activity monitoring, and post-class analysis; as well as concluding with a group's final report, thorough project display and presentation, and a detailed design record (Gusev et al., 2016).

Before class, the MOOC platform is mainly used to obtain the user's login times, video viewing times, video viewing duration, and frequency of posting replies as learning statistics analyze the students' enthusiasm and initiative in pre-class learning, and feedback for improvement. In order to ensure that students acquire the knowledge and develop the skills they need to progress, chapter tests are administered at regular intervals in order to systematically assess students' comprehension. In class, the teachers communicate with students about the feedback before class and answer questions. To better improve students' enthusiasm and initiative in classroom communication and discussion, students who actively ask and answer questions are scored, focusing on the evaluation of students' ability to ask questions and solve problems. The project is completed by group cooperation, normally 2-3 students. The group must showcase their cooperation results to the MOOC platform and present a speech in defense of them, with particular attention paid to the innovative perspectives of students, the scientific merit of the works, the overall composition and aesthetics, and the creative and technological methods for communicating and presenting. Furthermore, they provide advice on how to generate further improvements. To motivate the responsibility of team members, peer evaluation is carried out among members from the aspects of participation, contribution, communication ability, and

Figure 10. Blended Teaching Quality Evaluation Model



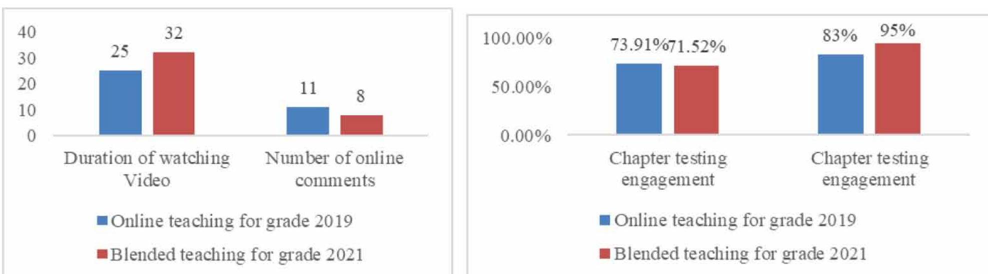
teamwork ability. After class, student's knowledge and skill proficiency are evaluated. By utilizing group-based, comprehensive projects that demonstrate effective defense and submitting training reports under the auspices of collaborative learning, students can accurately gauge and track changes in their academic achievements and personal abilities throughout their education. This evaluation process involves cataloging various types, phases, indicators, contents, and evaluation subjects to be included in the system (Table 1). Furthermore, the weight of certain indicators can be appropriately adjusted in keeping with blended teaching methods.

Table 1. Blended Teaching Quality Evaluation Index System

Type	Phase	Indicator	Content	Subject	Weight
Process evaluation	Pre-class evaluation	Student activity	Platform login times	Teacher	5%
		Video viewing times	Completeness and frequency		5%
		Video viewing duration	Duration and rumination ratio		10%
		Number of replies	Number of Posts and replies		5%
		Online learning test	Understanding and mastery		10%
	In-class evaluation	Classroom performance	questions and answers	Teachers students	5%
		Collaborative learning	Design and creativity	Teachers students	5%
	After-class evaluation	Unit project display	Design and creativity	Teachers students	10%
		Team contribution	Participation and ability	Student	5%
Summative evaluation	Final evaluation	Comprehensive project	Design and creativity	Teachers students	10%
		Online final exam	Understanding and mastery	Teacher	20%
		Design report	Report writing and summary	Teacher	10%

In 2020, since the epidemic started, students did not return to the university, and we used the MOOC platform to teach online, while in 2022, we switched to blended teaching in the university. As shown in Figure 11, the pre-course evaluation data of 92 online learning students and 158 blended learning students were chosen in 2020 and 2022 from the MOOC platform. As known from the average video viewing time, blended learning is about 7 hours longer than online learning, the reason is the fact that blended learning follows hands-on videos and requires repeated viewing, therefore, students' learning initiative is high. In addition, teachers and students can communicate face-to-face during blended learning, so online discussion is less active. The small difference in online test participation between the two teaching methods is blended learning students spend more time offline. The project completion data show that blended learning is higher than online teaching by about 12%, which directly determines students' mastery of the course and learning effect, and proves the important role of offline practice for teaching practical training courses.

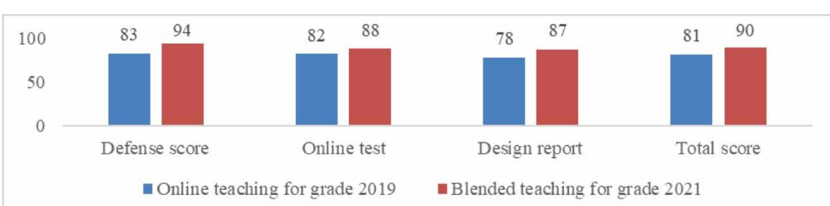
Figure 11. Pre-course Evaluation Data of the Online Learning and Blended Learning Students



The process evaluation also includes classroom and post-class evaluations. The classroom evaluation is based on students' classroom performance and teamwork, and the post-class evaluation is based on project presentation and group contribution. However, online teaching does not have these conditions and is not comparable to blended teaching. This also highlights the need and importance of blended teaching in practical courses.

Figure 12 shows the comparison data of the summative evaluation, the total score includes the defense score, online test, and design report. Overall, the scores of each item under blended learning are significantly higher than those of online learning, with the largest difference in defense scores. The offline teaching of blended learning can make the students complete the project production better and with higher quality. The design reports are significantly better than online learning regarding report length, content, and design results, reflecting that students under blended learning can think deeply and have their understanding and innovations. To sum up, practice can improve students' ability to

Figure 12. The Summative Evaluation Data

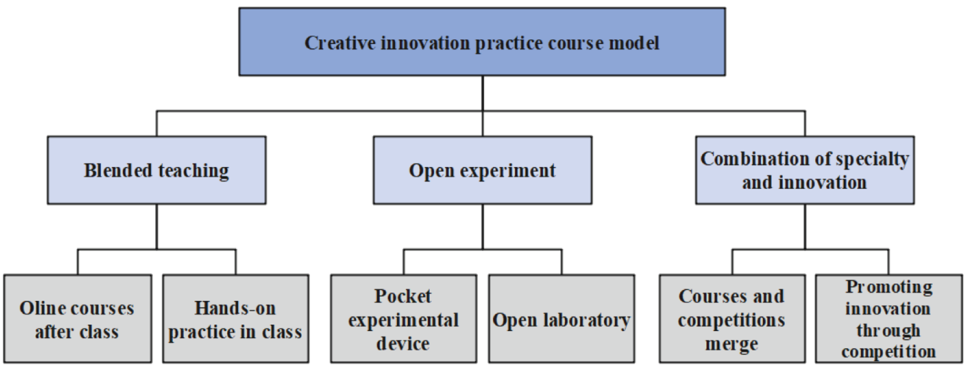


independent learning and enhance comprehensive quality, which also achieves the purpose of online and offline blended teaching.

CIP Courses Promote Students' Participation in Innovative Activities

According to the needs of professional innovation ability training, we have established creative innovation professional practice courses that match the subject competition. In recent years, we have combined the blended teaching of CIP courses with open experiments and practical innovation. We show the model structure of the course in Figure 13. The CIP curriculum promotes students' participation in practice and innovation, especially subject competition.

Figure 13. The Model Structure of CIP Course



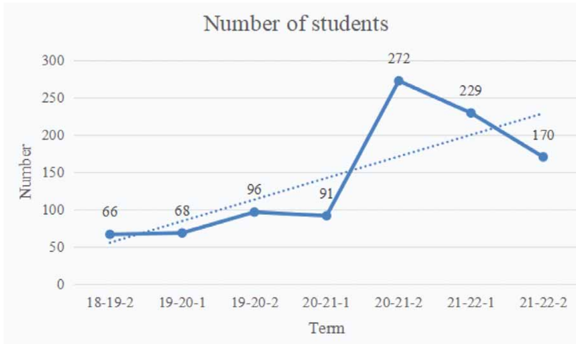
We take students as the center based on project engineering practice, and gradually expand competition courses such as electronic design, IoTs, smart cars, and robots from the first-year creative and innovative practice guide class, realizing the combination of course and competition. After several years of curriculum development, students' willingness to participate in practical innovation activities, such as subject competitions, has continued to increase. By 2017, student participation rates have generally exceeded 50%. After 2017, the student participation rate gradually reached 90% to 100% with implementing CIP and other courses. As a result, the practical innovation ability of students has been significantly improved. Taking electronic engineering as an example, recently students have won more than 300 awards at or above the provincial and ministerial level, including more than 40 national awards with more than 1,000 winners.

BLENDED TEACHING ANALYSIS AND REFLECTION

Course Selection

CIP has been offered in SDTBU for several semesters. With blended teaching practice, we find that this course plays an obvious role in improving students' creativity and innovation ability, and it is suitable as a basic practical course for electronic information majors. Currently, this course is highly appreciated by students and is chosen by many of them. Figure 14 shows the number of students enrolled in the last seven semesters.

Figure 14. Number of Courses Selected in the Recent Seven Semesters



Analysis and Effect of Blended Teaching Based on AHP

To improve blended teaching quality, we selected two majors to conduct a questionnaire survey on blended teaching after the second semester of the school year 2021-2022. As a result, 170 questionnaires were issued, and 154 completed responses were received.

The questionnaire included 65 specific indicators from three aspects of blended learning. Influencing factors of learning effect, students' learning factors, and blended learning effect were surveyed and analyzed by questionnaires of "strongly agree (G1)," "agree (G2)," "relatively agree (G3)," "relatively disagree (G4)," "disagree (G5)," and "strongly disagree (G6)."

Analytic Hierarchy Process (AHP) is an analytic method of hierarchy weight decision-making. The hierarchical analysis is used to assign weight to data for teaching optimization. Yaahp10.3 is an auxiliary software based on AHP, which can calculate the hierarchical weight. The questionnaire weight is optimized and analyzed by Yaahp10.3 to find out the indicators that need to be optimized and with better implementation for analysis. The type for calculating the n-th power root of the weight product of each row of the matrix is as follows:

$$\overline{w_i} = \sqrt[n]{\prod_{j=1}^{n} b_{ij}} \tag{1}$$

In type (1), b_{ij} is the data of row *i* and column *j* in the matrix, and n is the number of questionnaire indicators. $\overline{w_i}$ is the *n*-th power of the product of the *i*-th index data.

w_i is normalized to obtain the optimization weight of each indicator. The weight type is as follows:

$$w_i = \frac{\overline{w_i}}{\sum_{i=1}^{n} \overline{w_i}} \tag{2}$$

Calculate the eigenvalue a of the judgment matrix:

$$\lambda = \frac{1}{n} \sum_{i=1}^{n} \frac{(bw)_i}{w_i} \tag{3}$$

It is necessary to judge the Consistency Index (CI) to prevent the importance of weights from conflicting. If *CI* is 0, the data is completely consistent. If *CI* is larger, the inconsistency is higher:

$$CI = \frac{\lambda_{max-n}}{n-1} \tag{4}$$

To judge the degree of *CI* deviation from 0, the consistency ratio (*CR*) is introduced, and the random *CR* is calculated to judge whether it is less than 0.1. If *CR* is less than 0.1, it indicates that the collected matrix data and the quantitative value of the AHP evaluation scale are reasonable. Otherwise, the quantitative value of the AHP evaluation shall be adjusted. The calculation type of the *CR* index is:

$$CR = \frac{CI}{RI} \tag{5}$$

The corresponding data of the n-order matrix consistency index *RI* are shown in Table 2.

The evaluation scale values of AHP are quantified between 1 and 9, and are shown in Table 3.

The basic data questionnaire is as follows: The total number of students is 154, among which 78.57% are boys and 21.43% are girls. Statistics are made from learning terminals, learning places, networks, and average weekly online learning time. The specific data is shown in Figure 15.

The average time spent studying online is 5.535 hours per week, as shown in Figure 16.

From the statistical data, students mainly use mobile phones, tablets, and other mobile devices to learn through wireless networks currently, and the original non-learning places dormitories have already been the major places for learning to occur. It can be seen that with the popularization of mobile technology, online learning has entered students' life.

Table 2. The Corresponding Data of the n-order Matrix Consistency Index RI

n	RI	n	RI
1	0	4	0.89
2	0	5	1.12
3	0.52	6	1.24

Table 3. The Evaluation Scale Values of AHP are Quantified Between 1 and 9

The importance of i compared to j	Quantitative values
Extremely important	9
Highly important	7
Comparatively important	5
Moderately important	3
Equally important	1
Adjacent value	2,4,6,8

Figure 15. The Basic Questionnaire Data

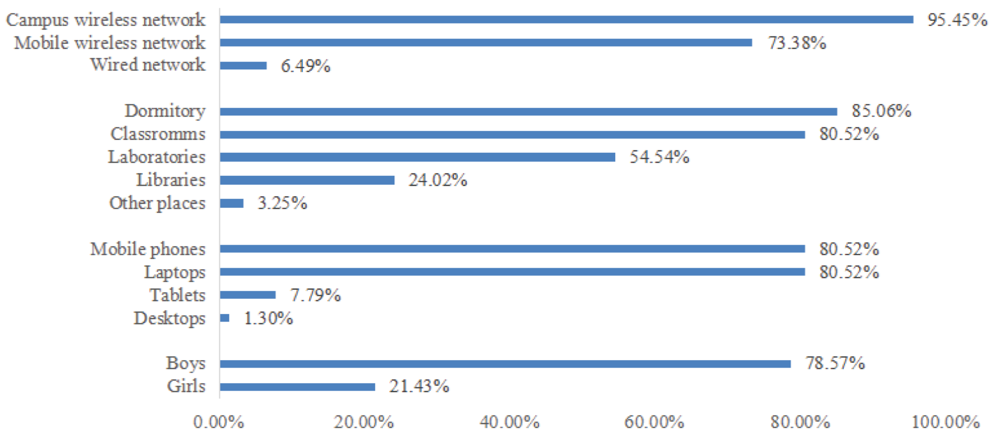
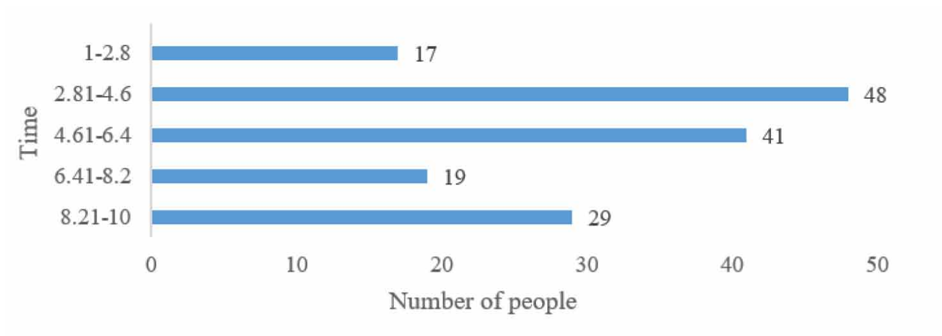


Figure 16. The Average Weekly Online Learning Time



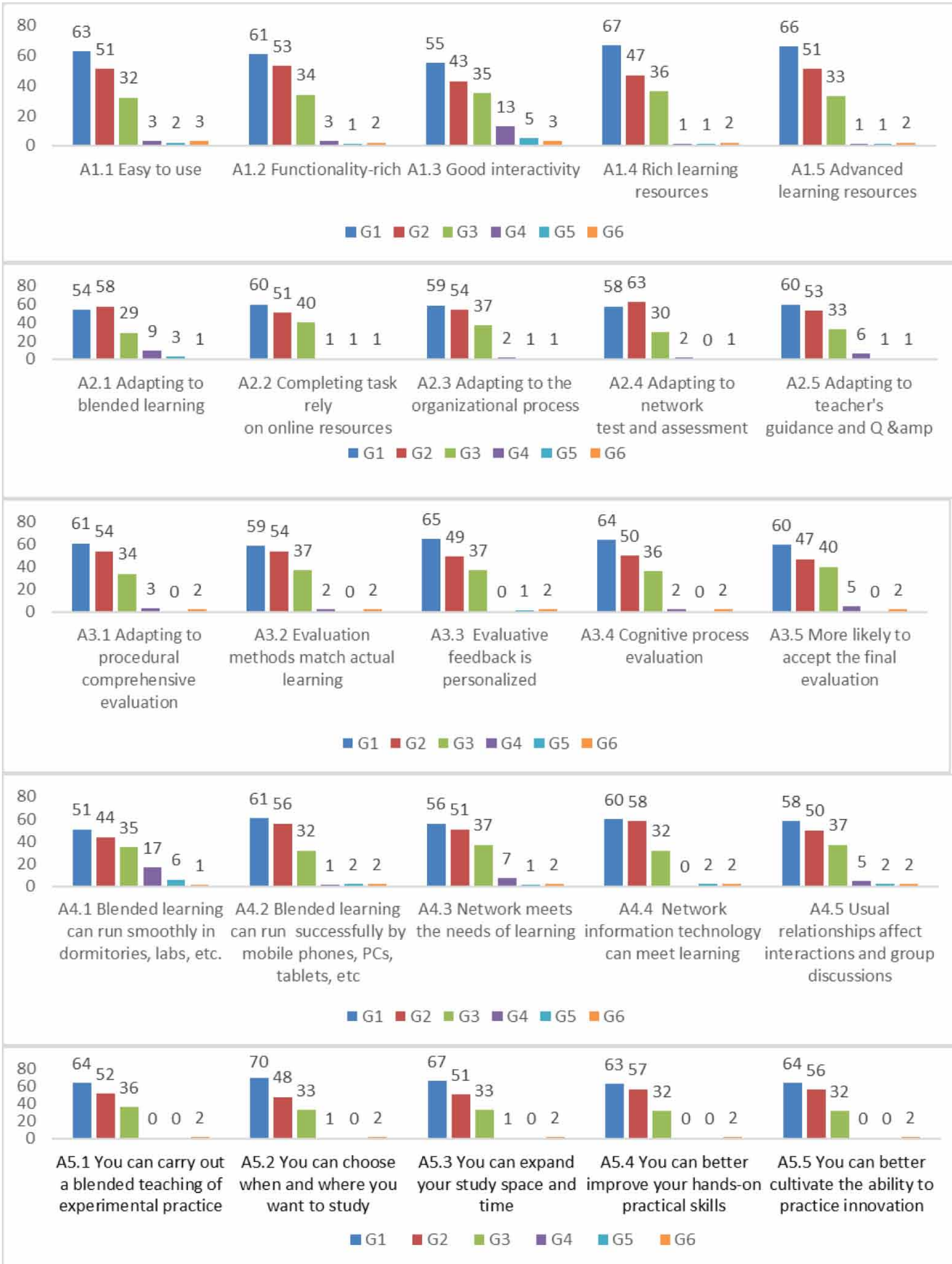
First of all, the factors influencing the learning effect in blended learning (A) include five aspects: network platform factor (A1), teaching method factor (A2), evaluation method factor (A3), teaching environment factor (A4), open experimental practice environment (A5). Therefore, the optimization weights are as follows:

A1.1~A1.5:0.0382,0.0277,0.1765,0.0247,0.0247
A2.1~A2.5:0.0519,0.013,0.013,0.013,0.026
A3.1~A3.5:0.0143,0.0143,0.0143,0.0143,0.0143
A4.1~A4.5:0.3035,0.0313,0.0631,0.0283,0.0575
A5.1~A5.5:0.0072,0.0072,0.0072,0.0072,0.0072

The corresponding questionnaire results are shown in Figure 17.

Firstly, for the network platform factor, except for good interactivity of the network platform (A1.5), 87.67% of all students agreed, and 12.33% of them disagreed. In other aspects, more than 95% agreed. Among the teaching method factors, the agreement on the five aspects of teaching factors is more than 95%, indicating that blended teaching has great teaching advantages in the five aspects of teaching factors. Moreover, more than 95% of all students are satisfied with these methods on the

Figure 17. The Questionnaire Results for Factors Influencing Learning Effect in Blended Learning A (A1-A5)



factors of evaluation methods. Compared with the traditional teaching evaluation methods, blended teaching can better show students' comprehensive quality. Finally, less than 90% of all students are satisfied with A4.1's "learning place." Comparatively speaking, students have higher requirements for the learning environment of practical courses. Noisy canteens and quiet libraries are not suitable for online teaching of practical courses, while the open laboratory environment is relatively free and well-equipped. Which is a relatively ideal place for classes. From the weight distribution of learning effect factors, A5 (open experimental practice environment) is the lowest weight, indicating that A5 is the dominant factor of blended practical teaching. The secondary indicator with the largest optimization weight is A4 (teaching environment), which needs to be optimized the most. In A4, the maximum weight of the blended teaching place (A4.1) is 0.3035. The comparison of A4 and A5 shows that students have not been provided with an ideal online and offline learning place. Compared with the traditional classroom or library, the open laboratory is more suitable for the blended practical teaching mode. In addition, the weight of network platform interactivity (A1.3) is 0.1765, which indicates that it is also a teaching focal point in urgent need of improvement.

Secondly, the questionnaire on students' learning factors in blended learning (B) includes four aspects: learning attitude (B1), learning participation (B2), learning motivation (B3), and learning habits (B4). The optimization weights are as follows:

B1.1~B1.5: 0.0087,0.0087,0.0087,0.0087,0.0087
B2.1~B2.5: 0.2763, 0.0338,0.0402,0.0275,0.0703
B3.1~B3.5: 0.0116,0.0111,0.0484,0.0116,0.0116
B4.1~B4.5: 0.0262, 0.0307, 0.0645,0.1343,0.1585

The corresponding questionnaire results are shown in Figure 18.

As shown in Figure 18, except for B2.1, B2.5, B3.3, B4.3, B4.4, and B4.5, the satisfaction of other indicators is more than 95%. These include learning participation and progress. Because students can take away experimental devices and use their spare time to learn, they can keep up with the progress, which shows that students have greater interest and curiosity in blended practical courses, and their enthusiasm for participation is relatively high. From the overall perspective of students' learning factors, the weights of learning participation (B2) and learning habits (B4) are large. Through the investigation of students, we know that, as with the project-based tasks conducted within groups, each team member's motivation and sense of participation are different, and the sense of participation is different. Among them, B2.1 has a larger weight of 0.2763, and 10.4% of students think they do not have a sufficient opportunity to express themselves, which is related to the poor interaction of online teaching mentioned above. The difference between this novel blended practice course and the traditional teaching method also causes difficulties for some students to adapt, and as a result, they fail to give feedback timely on the intractable problems encountered in learning.

Thirdly, the questionnaire on the blended learning effect (C) includes four aspects: knowledge acquired (C1), ability improvement (C2), learning experience (C3), and learning quality (C4) to determine whether it helps to improve the quality of teaching and students' classes. The optimization weights are as follows:

C1.1~C1.5: 0.0111,0.0149,0.0096,0.0111,0.0096
C2.1~C2.5: 0.0263,0.0132,0.0263,0.0263,0.0132
C3.1 ~C3.5: 0.1849,0.087,0.3224,0.0576,0.0643
C4.1~C4.5: 0.0144,0.0629,0.015,0.015,0.015

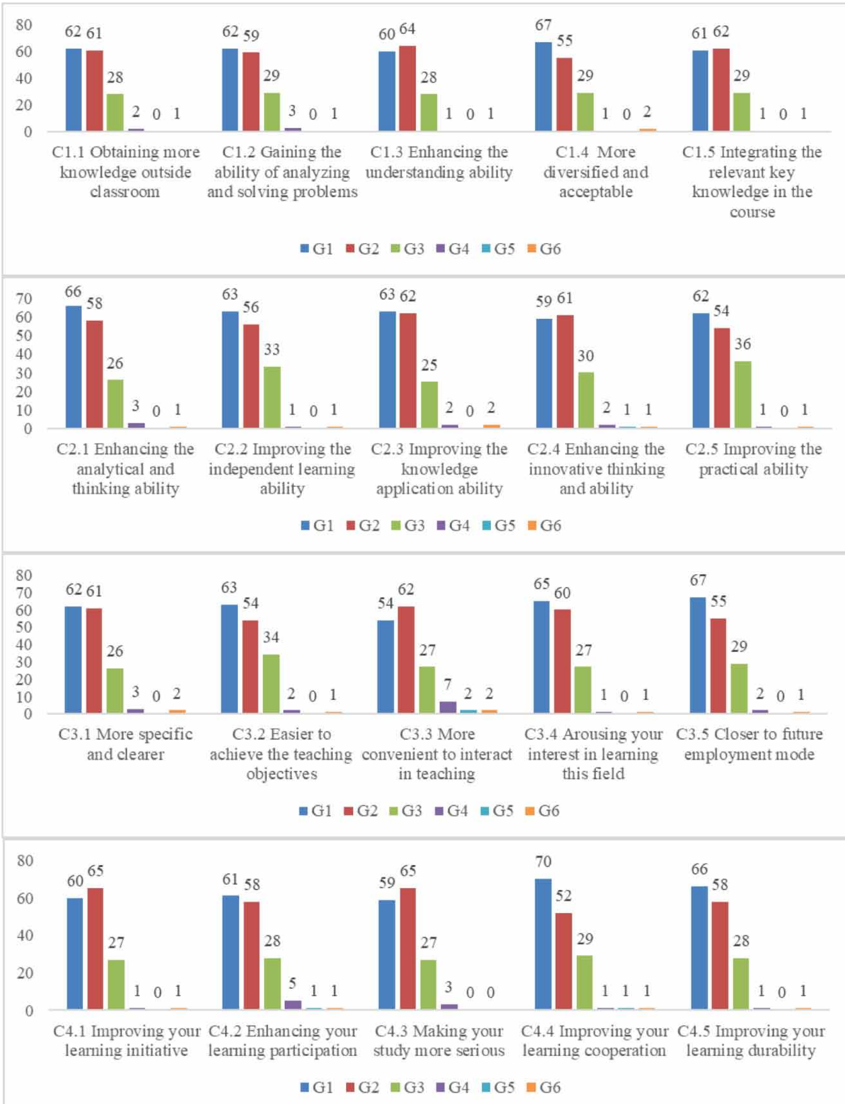
The questionnaire results are shown in Figure 19.

Overall, the weight of knowledge harvest (C1), ability improvement (C2), learning experience (C3), and learning quality (C4) in the blended learning effect is 0.0562, 0.1053, 0.7162, and 0.1223, respectively. It can be seen that students have a high recognition rate of knowledge harvest, which has achieved the goal of improving knowledge, solving problems, and diversifying learning. Among them, learning experience (C3) has the largest weight, so it needs to be optimized the most. By analyzing the

Figure 18. The Questionnaire Results of Students' Learning Factors in Blended Learning B (B1-B4)

satisfaction degree of each item under learning experience (C3), we can see that C3.3 has the largest weight of 0.3224. The reason is that the students of online learning practice courses mostly use online videos and network resources to operate. Inevitably, they will encounter problems that have not been explained. The teachers cannot provide face-to-face guidance. The efficiency of problem-solving is low, and the interactivity is relatively poor. Therefore, we can establish a video platform for practical difficulties to allow students to upload the problems encountered in the operation into videos. Students

Figure 19. The Questionnaire Results of Blended Learning Effect C (C1-C4)



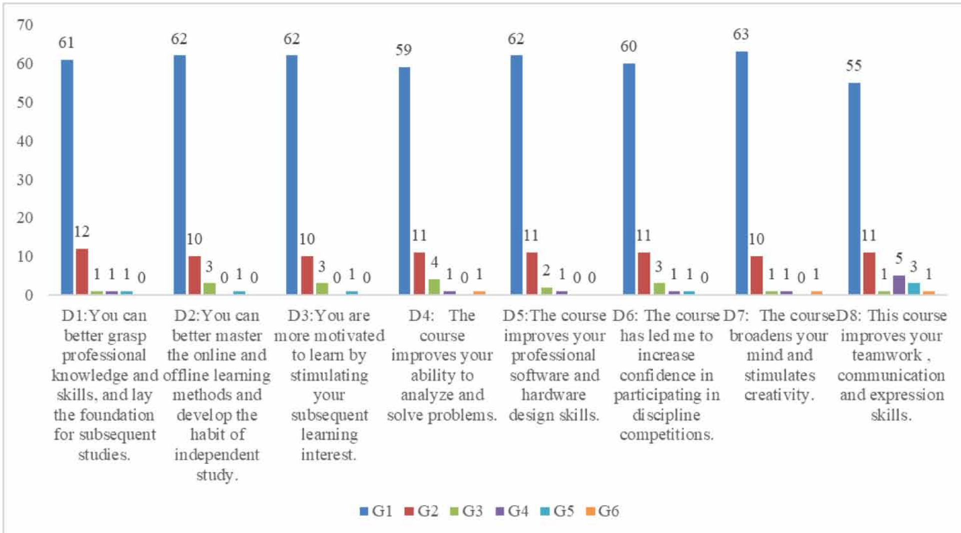
can leave messages and discuss with each other. Teachers can reply to unsolved problems in a unified way to improve the interaction between teachers and students and among students.

Blended Teaching Influence on Students' Follow-Up Learning

For 76 juniors who have finished the course for two years, a questionnaire was conducted to investigate the impact of blended teaching of "CIP" on students' follow-up learning (D) in Figure 20.

As shown in Figure 20, after two years of learning and precipitation, students have a deeper understanding of the advantages of blended teaching methods. However, D8's satisfaction is relatively low. One possible reason is related to students' professional level and personality. Students are different in their abilities to assimilate new ideas and express themselves. It may also be caused by improper grouping. In general, the blended teaching method greatly impacts students' later learning

Figure 20. Questionnaire Results of the Impact on Students' Follow-up Learning D (D1-D8)



careers. From the interest inspiration to the subsequent professional learning and employment choice, it improves the confidence in discipline competition and practical innovation and achieves the goal of comprehensive and practical talent personnel training.

Performance Correlation Analysis

Through the Pearson correlation test of 176 students in two majors this semester, it can be found that student's participation in online learning and offline teamwork learning is highly consistent, which means that students with higher offline learning enthusiasm have higher online self-learning enthusiasm and initiative (Table 4). Furthermore, the more visits to the online learning platform, the higher the students' course scores; the greater the students' participation and contribution in-group cooperation, the higher the course examination scores. There is a significant correlation between the two at the level of 0.01 (bilateral). To enhance the students' learning autonomy, encourage their cooperative learning enthusiasm and initiative, and ultimately improve their academic performance, teachers must create regulative guidelines for both online and offline education when instructing through a blended teaching methodology.

Through the correlation analysis between daily performance and course performance, we found that the two aspects are significantly correlated at the level of 0.01 (bilateral), which shows that in the blended teaching process, teachers' guidance, supervision, and regulation of students' online and offline learning process play an important role in ensuring students' mastery of knowledge and skill proficiency. Furthermore, from another aspect, it also responds effectively that blended teaching can not only improve

Table 4. Performance Correlation Analysis

	Platform access score	Offline learning score	Total course score
Platform access score	1	0.634*	0.482*
Offline learning score	0.634*	1	0.671*
Total course score	0.482*	0.673*	1

Note: * is significantly correlated at 0.01 level (bilateral) students' learning quality, but also effectively promote the cultivation of students' autonomous learning ability, team cooperation ability, communication ability, and innovative thinking ability.

Teaching Reflection

Meanwhile, some problems were discovered during this practice and inspired the author's thinking such as how to maintain students' enthusiasm for participating in the blended teaching methods for a long time, and whether the mobile terminal entering the classroom will have a negative impact and which methods will be more effective.

Given the above problems, we have learned from the survey of students participating in the online assessment that, first, more information needs to be added to the content of the course. To ensure long-term enthusiasm for learning, students and teachers must complete it together. Teachers should innovate teaching methods in blended teaching, and add more interesting, interaction, and socially practical content. Second, blended practical teaching needs further improvement according to students' level. Students decide the progress of online courses and practice. All students must complete the project at the end of the course. Third, in view of the proliferation of handheld devices, schools should take full advantage of them by implementing on-site online check-ins and questioning strategies. This approach can complement more traditional classroom teaching methods and help unknowingly stimulate student engagement and excitement. Fourth, the blended teaching place of practical courses also needs further improvement. The traditional teaching place cannot meet the students' hands-on practice. Fifth, the interaction between students and teachers and among students is poor, especially in online teaching. We should continue to explore how blended teaching can make up for the shortcomings of online teaching.

To foster a more beneficial learning atmosphere, it is essential to enhance laboratory conditions and source experimental apparatus so that learners can partake in experiments anytime and receive individualized instruction in smaller groups. To promote a positive collaboration between educators and learners, address student inquiries, and foster creativity, this course promotes interest in the subject material based on teaching modules, encourages group work, elevates the impact of experiential endeavors, and heightens difficulty within the curriculum to ensure successful academic results.

CONCLUSION

By implementing the conception of personnel training in engineering with an open approach, we have been able to create a diverse teaching modality for CIP experimental practice courses through several semesters of experimentation. This modality seamlessly blends together online and offline platforms, both in-classroom and out-of-classroom instruction, as well as laboratory activities both in and outside the lab, alongside classes associated with competitions. Through investigation and analysis, we have found that blended teaching effectively promotes students' interest in learning and inspires their subjective initiative.

The course achieves student-centeredness, combines theory and practice, designs diverse teaching contents, integrates knowledge into project engineering cases, and practices them. As a result, students gain knowledge and ability from course practice, and course learning adds scientific spirit for students, leading to exploration and personalized learning, forming a project-driven curriculum.

The course deeply integrates modern information technology with teaching, uses high-quality network resources, and expands the breadth and depth. In addition, the course's online platform has the functions of learning process tracking and process analysis, which can give timely feedback and analysis on learning progress and quality, and play the role of guiding teachers in implementing teaching strategies and motivating students to learn.

The blended teaching of the course provides a comprehensive evaluation of students' learning performance from multiple aspects and perspectives, focusing on both the learning process and the learning effect. From the teacher's perspective, the mutual adoption of MOOC online and face-to-face teaching allows personalized adjustment of training objectives based on student characteristics, making teaching more relevant and improving the efficiency and quality of teaching.

After investigation, students have a high degree of recognition, which is suitable for the long-term promotion of teaching, while some aspects need further improvement. For example, compared with general lecture courses, laboratory environment, portability of experimental equipment, student participation, team cooperation, teacher-student interaction, and project-based presentation of online courses are required for experimental practice courses. In the future, combining our practical experience received in recent years, we will continue implementing and improving the "Creative and Innovative Practice" blended teaching, finally forming a complete curriculum system to help students grow and progress.

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