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Application of Design-Based Learning and Outcome-Based Education in Basic Industrial Engineering Teaching: A New Teaching Method

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Abstract: This paper provides and illustrates a design-based learning (DBL) and outcome-based education (OBE) approach for fostering the innovation, practice, and autonomous learning ability of industrial engineering students. We performed two studies with on industrial engineering students in typical educational activities. The first study used a topic of "sheet metal parts turnover protection optimization" to explore the application effect of "DBL + OBE" and its shortcomings in the implementation process, so as to help students understand this new teaching method. Then, in order to verify the use effect of "DBL + OBE", the second study used the topic of "production line balance" to divide the students into an experimental class and a control class. The experimental class adopted the design learning teaching method, while the control class adopted the traditional teaching method. In order to verify the effectiveness of the proposed method, students and teachers were interviewed. It was found that the students in the experimental class were more outstanding in personal abilities, such as systematic thinking, independent innovation ability, etc. The results show that: the rational use of design-based learning and outcome-based education concept can stimulate students' interest in learning, cultivate students' team spirit, improve students' innovation ability, practical ability and problem solving ability, and cultivate "innovative talents" needed in the new era.

Keywords: basic industrial engineering teaching; design-based learning; outcome-based education concept; production line balance

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1. Introduction

To improve the teaching level of the Industrial Engineering and cultivate students' practical and innovative abilities, Chinese teachers often introduce some new teaching methods into the classroom for research. Ai et al. (2020) divided these research projects into two categories. The first is the research based on practice and innovation ability [1]. For example, Wang et al. (2017) improved students' problem-solving ability and exercised innovative thinking by building an experimental simulation platform [2]. Wang et al. (2005) proposed a construction scheme and experimental teaching plan for industrial engineering practice teaching in order to improve students' practical ability and innovation ability, and adapt to the development of industrial engineering discipline and the society's requirements for senior talents [3]. The second is to study some new teaching forms and try to introduce them into the classroom to explore their effects. For example, Kuppuswamy et al. (2020) applied project-based learning (PjBL) to mechanical engineering design course and offered students the opportunities to experience engineering design the way it is practiced and simulated in industry [4]. Wu et al. (2020) applied the project-based learning (PjBL) and SCAMPER teaching strategies in engineering education to explore the influence of creativity on cognition, personal motivation, and personality traits [5]. Brian et al. (2020) applied problem-based learning (PBL) in the teaching of biology courses, and students expressed that PBL was very effective in helping them learn [6].

Although the above research and teaching activities are effective in improving students' practical and innovative abilities, there are still many shortcomings. Firstly, since the teachers generally have not received professional teacher training [7], the research methods were not mature in the initial research. Secondly, students' dominance and initiative are not taken into account in the method research, so students are still passive in learning. Such project-based learning activities often take the final output as the main goal [8], but do not foster students' innovation and practical ability.

Therefore, in recent years, more scholars have begun to study a new learning style—Design-Based Learning (DBL). Design-based learning (DBL) was initially proposed by Gijselaers in 1996, based on a problem-based learning (PBL) and project-based learning (PjBL) model [9]. Sun et al. (2016) summarized the understanding and recognition of design-based learning (DBL) by different international researchers. He pointed out that Kolodner believes that design-based learning is a new learning method with the goal being to cultivate students' basic skills and high-level critical thinking. The formation of these forms of thinking and abilities can enable students to have a deeper understanding of the subjects they are studying [10]. Sonia et al. (2013) believed that design-based learning is a teaching method that forms innovative products, methods, and systems in the process of inquiry and reasoning. She also pointed out that this teaching method can better encourage students to learn scientific knowledge [11]. Fortus et al. (2004) also believed that design-based learning was a teaching method, and the scientific knowledge and problem-solving skills in teaching were built in the context of designing creations. At the same time, he also pointed out that the highest experience for students is not to design products, but to independently construct scientific knowledge through product design [12,13].

Although different scholars have different definitions of design-based learning, their concepts and connotations are the same. Design-based learning (DBL) is a learning and teaching approach through design as the learning activity. It is different from the traditional classroom with teachers as facilitators, since students are the main part of the learning process in design-based learning. Teachers propose challenging tasks and allow students to brainstorm design ideas that reflects the theme, concepts, and standards of the project task, using the knowledge they already have. When implementing the design plan, students continue to learn new knowledge and then apply what they re-design to an idea or a prototype. Applying new knowledge to the design plan, constantly improving and optimizing the plan, and learning technology by doing make this a process of repeated cycles [14].

From the definition and development process of DBL, DBL is a combination of project-based learning and problem-based learning approaches [9]. Its outstanding features include teamwork, fusion of subject knowledge, extensive learning objects, multiple learning objectives, learning cycle iteration, design activities throughout the entire learning process, etc. [15].

Based on the above research, many scholars at home and abroad started trying to introduce design-based learning (DBL) into the classroom and verify its effects. For example, Matthew et al. (2012) applied design-based learning to the classroom, and from the perspective of students, discussed students' views on DBL in curriculums, DBL in graduation projects, and DBL in engineering careers. Through the qualitative and quantitative analysis of this survey, students can have a better understanding of DBL in the learning process, and students' opinions can help verify, improve, or reject this useful teaching tool [16]. Yang et al. (2017) conducted "design-based learning" teaching exploration in a course, which changed students' learning concepts, improved students' learning initiative, exercised students' thinking ability, and cultivated enhance students' collaborative communication ability, problem-solving ability, and innovative thinking ability [17]. Ellefson et al. (2008) applied design-based learning to biology teaching; the experience of teachers and the progress of students showed that design bacteria succeeded in teaching the core aspects of gene expression through DBL [18].

The above-mentioned teaching activities and research have achieved some good results, but some research only focuses on the theory of design-based learning, or repeatedly explore its application effect after many scholars have verified the characteristics and application effect of design-based learning. Industrial engineering is an intersecting subject and a highly practical applied subject. Its professional training goals require students to have both solid and rich theoretical knowledge, as well as strong communication skills, innovation capabilities, and management ability and practical ability [19]. With the rise of Industry 4.0, national demands for industrial engineering talents have greatly increased. The traditional teaching model obviously cannot meet the demand for industrial engineering talents in today's society. Many school curricula and teaching practices have been criticized because their academicism does not give students experience with real-world problems [20]. The transition towards more learner-centered curricula has become a worldwide trend in engineering education [21]. As the main channel for cultivating industrial engineering talents, colleges and universities should adjust and reform their talent training mode to meet the challenges of industry 4.0 [22]. In this research, the authors propose a new teaching method to apply the concept of outcome-based education (OBE), which was proposed by Spady in 1981 and started to be implemented in the United States in 1994 [23]. We combined OBE with the concept of design-based learning (DBL) to the teaching of industrial engineering and explored its application effect.

The concept of outcome-based education (OBE) is an educational concept based on students' final learning results. It believes that the objectives of teaching implementation and teaching design are the results achieved by students through the educational process. First, it is necessary to decide what is important to students, and then organize courses, teach, and evaluate [24]. Outcome-based education is "reverse design", which clarifies the ultimate goal that students need to achieve in their learning, and then designs the teaching plan in turn. With the student as the center, the teacher designs personalized teaching according to the individual differences of each student [25]. Outcome-based education emphasizes that everyone can "succeed". This kind of success in the traditional sense does not only refer to achieving good results, but also includes the ability of students to develop core abilities in life and work in the learning process, thus education is more concerned with the cultivation of students' comprehensive qualities and abilities [26]. Teachers should focus on helping students develop knowledge, skills, and behaviors so that they can achieve clear expected results [27].

Many teachers tried to apply the outcome-based education to the course teaching and had achieved certain results. Liang Qiang (2020) applied the concept of outcome-based education to a business English curriculum, and explored the reverse design strategy of the business English curriculum from the perspective of curriculum objective optimization, curriculum practice design, and curriculum teaching evaluation [25]. Li Xiaona (2020) applied the outcome-based education to the practice teaching of mechanical specialty, constructed the hierarchical practice teaching system and teaching quality system, and really solved the problem of realizing the teaching goal of mechanical specialty under the background of practice teaching reform [28]. Zhang Xinyan et al. (2018) applied outcome-based education to industrial engineering teaching, and established an OBE-based course evaluation system, which was of great significance for cultivating high-quality and innovative industrial engineering professionals [29]. Sun Xiufang (2019) applied the outcome-based education to the comprehensive practice class of industrial engineering. Through the analysis of the learners' learning effect, it showed that the class designed by the model improved students' learning initiative and the efficiency of knowledge acquisition.

The goal of outcome-based education (OBE) is the learning outcomes of students, emphasizing that what students have learned and whether they succeed is more important than how to learn and when to learn. According to the different characteristics of students, teachers provide suitable learning opportunities for each student, let students complete challenging tasks in the form of group cooperation, and cultivate students' practical ability. Teachers play a guiding role in this process, using demonstration and strategies such as grouping, evaluation, and feedback that help students to achieve expected results [30]. From this point of view, design-based learning (DBL) and outcome-based education (OBE) have many similarities. Combining the two effectively and applying them to teaching can improve the shortcomings of traditional teaching methods effectively and achieve good results.

2. Industrial Engineering Course-Design-Based Learning Education

2.1. Traditional Teaching Methods of Basic Industrial Engineering

The basic goal of industrial engineering is to reduce costs and improve quality and productivity [31]. It is a comprehensive system of applied knowledge, which mainly reflects in the intersection of management and engineering knowledge. It uses the relevant knowledge of social science and natural science comprehensively to determine, predict, and evaluate the production system. This major requires not only solid basic theoretical knowledge, but also strong practical ability.

However, traditional industrial engineering teaching tends to concentrate on the teaching of theoretical knowledge and neglect the cultivation of practical ability, leading to the situation that many students have rich theoretical knowledge and weak practical ability [32]. Traditional industrial engineering teaching is mainly divided into two aspects: classroom teaching and experimental teaching. In class teaching, teachers generally make presentation slides (PPT) with knowledge points in the textbook, interspersed with some pictures or videos, and occasionally ask questions to students. Students are in a passive learning state with low learning enthusiasm. Experimental teaching is generally for teachers to teach experimental methods and experimental precautions, grouping, and then students are working in the laboratory to conduct experiments. Students' experimental methods are generally carried out according to the teacher's explanation and seldom done actively. In addition, for the experiments conducted by proceeding groups, some members of the group were very enthusiastic, but some students showed a negative attitude and did not master the content of the experiment. Therefore, traditional industrial engineering teaching is not conducive to cultivating students' hands-on, creative, and practical abilities. Figure 1 shows the traditional teaching mode of industrial engineering [32].

2.2. Characteristics of Industrial Engineering Courses

Industrial engineering is a comprehensive applied knowledge system. Its comprehensiveness mainly reflect the organic combination of management and technology [33]. Industrial engineering originated from scientific management and has management characteristics. It is often regarded as a form of management technology [34]. It can be reflected in the engineering curriculum, since most industrial engineering courses in colleges and universities include management, statistics, microeconomics, marketing, etc. Some industrial engineering majors also belong to the management department, which reflect their management characteristics.

Industrial engineering (IE) is different from management. It has obvious engineering attributes [35]. IE students have to learn a lot of engineering technology, mathematics, and mechanical courses such as logistics system design, facility planning, etc. This feature is also reflected in the curriculum of industrial engineering. Its professional courses include mechanical design, advanced mathematics, production planning and control, facility planning, etc. [36].

Industrial engineering is different from general engineering disciplines. It is not only applies natural science and engineering technology, but also applies social, humanistic, and economic management knowledge, which also reflects the comprehensive nature of it [37].

From the perspective of the characteristics of industrial engineering courses, only relying on the traditional teaching methods cannot make students fully grasp industrial engineering, and cannot really cultivate the industrial engineering talents needed by society. Therefore, it is very necessary to change the traditional teaching methods and adopt new teaching methods.

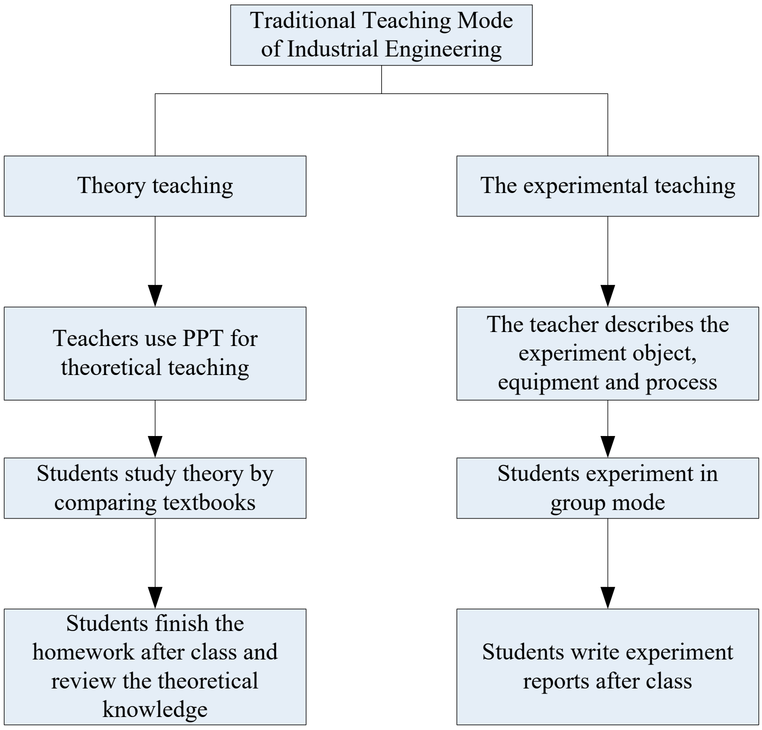

Figure 1. Traditional teaching mode of industrial engineering.

2.3. Industrial Engineering Course Teaching Based on Design-Based Learning and Outcome-Based Education

Industrial engineering requires extensive expertise in management and engineering knowledge, good interpersonal relationships, a spirit of continuous innovation, an overall system concept, and the pursuit of endless rationalization [38]. However, based on the traditional teaching methods, it is difficult to cultivate innovative talents with the above characteristics. Here we propose a new teaching method that combines the concept of design-based learning (DBL) with the teaching of industrial engineering, focusing on "learning" and supplementing by "teaching" so that students become the main body of the classroom, using the "combination of learning and thinking" [39] to conduct research learning and innovative experiments to improve the comprehensive quality of students. At the same time, combined with the concept of outcome-based education (OBE), first, it is clear that the training goal is to cultivate students' innovative thinking, critical thinking, practical ability, and independent learning ability, and to design the teaching process with this goal as the guide. This paper uses two typical operation models of design-based learning: the "reverse thinking" model, based on the scientific inquiry model of design [40], combined with the idea of "reverse design" of outcome-based education, from the perspective of teacher-student activities and teaching environment, constructs the activity framework of design-based learning and outcome-based education, as shown in Figure 2.

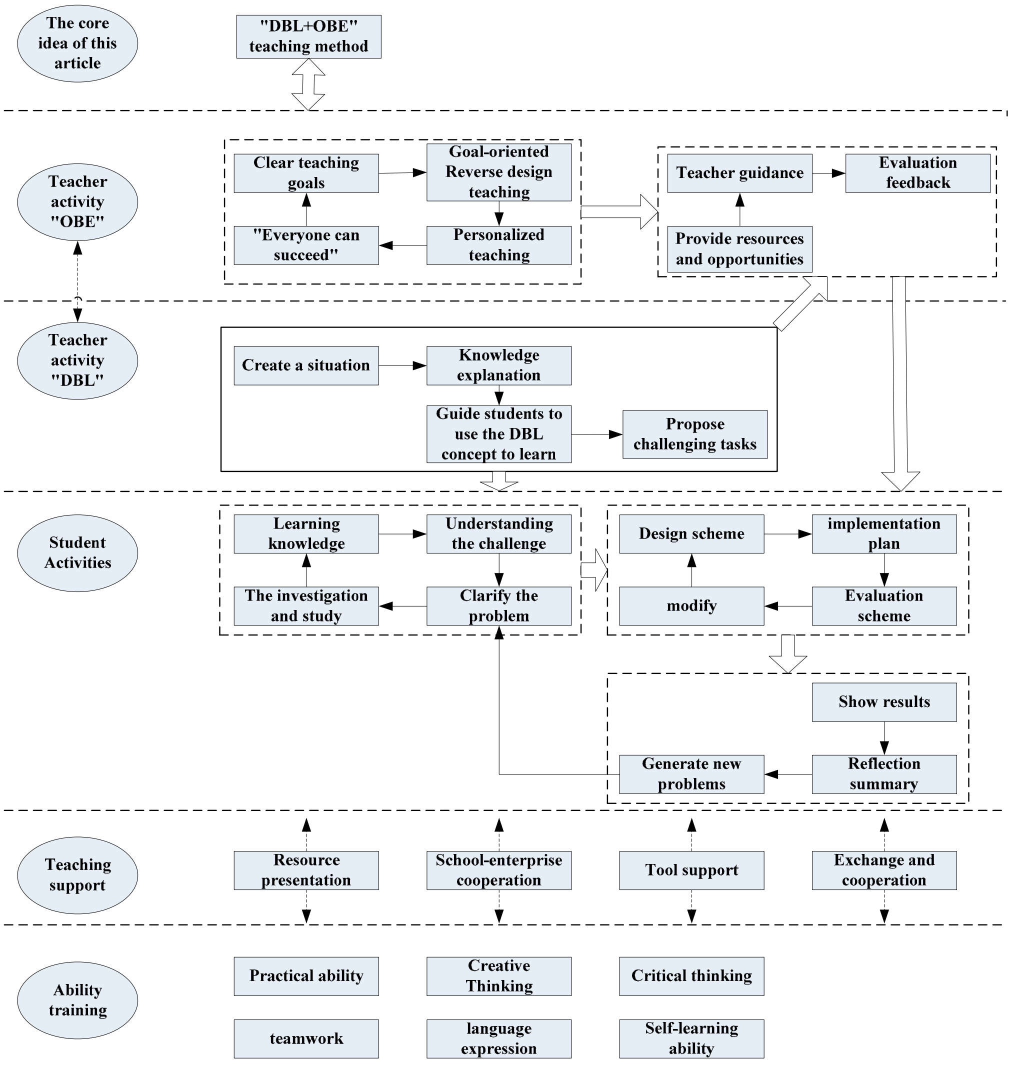

Figure 2. Design-based Learning (DBL)+ Outcome-based Education (OBE)" teaching model.

2.3.1. Teachers Activities (Outcome-Based Education)

From the perspective of teachers, teachers play the role of guide, helper, and evaluator in the whole teaching activities. In terms of industrial engineering teaching, we combine the theoretical teaching and experimental teaching, and the classroom is no longer a single classroom. The combination of theory and practice is more conducive to students' understanding of knowledge and a clearer grasp of the content and purpose of the experiment.

The first step is to clarify the teaching objectives. Take the basic industrial engineering course as an example, firstly, teachers need to clarify what knowledge and skills students are expected to master upon completion of the course, such as a learning curve, operation analysis, movement analysis, and 5S management. Not only do students need to master theoretical knowledge, but also learn to apply it in practice. Secondly, teachers need to clarify what abilities the students should have cultivated and improved after the course is completed. Taking basic industrial engineering as an example, after the course is over, students have the ability to identify on-site waste and find ways to improve it, such as action waste and so on, while they can find the unreasonable aspects of 5S on site and propose solutions.

The second step is to design teaching in reverse based on the goal. The teacher designs the teaching plan according to the teaching goal and classifies the knowledge points.

The third step, according to the characteristics of different students, individualized teaching methods, teaching contents, experimental projects, and teaching requirements and methods should be different to cater for different characteristics of students; for example, some knowledge points can be grasped by students through classroom teaching while for some knowledge, students must practice to really grasp it. In the process of teaching students in accordance with their aptitude, teachers should monitor the development process of students and make timely corrections [41].

The fourth step is that teachers should adhere to the concept that "everyone can succeed" and believe that every student can achieve the ultimate learning goal through learning, which requires teachers to provide students with appropriate learning opportunities and guarantee that every student has the opportunity to achieve learning outcomes in terms of time and resources [42].

2.3.2. Teachers Activities (Design-Based Learning)

The first step is creating situations. At the beginning of teaching activities, teachers should create situations according to the theme of this lesson. When creating situations, teachers should meet the following four points [43]: (1) Interesting. The problems should be interesting, challenging, and related to students' lives. The design of problems and activities should be able to stimulate learners' intrinsic learning motivation and the solution for problems should enable students to have a sense of achievement; (2) Experiential. It is necessary for students to use their hands and brains to participate in the learning process independently. In the process of participation, experience, and knowledge acquisition, students not only obtain the result knowledge, but also obtain the process knowledge contained in the process of project problem solving; (3) Situational. This emphasizes that students should acquire the ability of situational application of knowledge, and be able to understand and identify the knowledge performance of different situations, that is to say they should be able to use the learned knowledge to solve practical problems flexibly; (4) Collaboration. Teachers guide students to follow the principle of heterogeneity within the group to form a design group to collect and analyze learning materials, put forward and verify hypotheses, and evaluate learning outcomes.

The second step is knowledge explanation. According to the needs of students' knowledge and skills, teachers should focus on and selectively explain textbook knowledge to help students solve difficult problems.

The third step is to guide students to use the DBL concept to study independently, according to the research of Fortus (2004), the process of design-based learning can be divided into seven stages [12]: (1) Identify and define the problem; (2) Gather and analyze information; (3) Determine performance criteria for successful solutions; (4) Generate alternative solutions and build prototypes; (5) Evaluate and select appropriate solutions; (6) Implement choices; (7) Evaluate outcomes.

The fourth step is to challenge. In the specific situation, the teacher sends out the challenge task to the students, and presents the specific content of the challenge task through explanation, demonstration, and other methods.

In the two teaching processes of DBL and OBE, the common activities teacher's needs are: first, providing resources and opportunities. Teachers should provide necessary resources and tools for students to carry out design-based learning activities; second, providing the teacher's guidance. Guide the students in the process of learning and designing the scheme. Find and correct the students' mistakes in time, record and analyze the error prone points, and encourage the students to learn new knowledge and improve the scheme; third, provide evaluation feedback. After the students complete the design-based learning scheme, the teacher gives an evaluation standard, and the students modify and optimize the scheme according to this standard, and summarize the shortcomings and progress of the design-based learning process, so as to evaluate and share with each other.

2.3.3. Students Activities

(1) To learn knowledge. Students should have an overall grasp of the knowledge of the course and make clear the key and difficult points of the course.
(2) To understand the challenge. Students should understand the challenge task issued by teachers, contact their original knowledge system, and make clear what they need to do.
(3) To make clear what the problems are. Students should make clear the problems that must be solved to complete the challenging tasks, combine the existing resource conditions, and conceive of their own "how to do" process.
(4) To investigate and research, through the problem analysis, students have a direct demand for knowledge and skills, and conduct related investigations and studies on the required knowledge, skills, and information to obtain solutions to problems.
(5) To design a plan. The team members use their knowledge and experience to design a feasible and creative plan according to the teacher's requirements.
(6) To implement the plan. After the scheme design is completed, the scheme is implemented.
(7) To modify the plan. In the process of implementing the plan, students should record the shortcomings of the plan and pay attention to whether the plan meets the requirements of the teachers and whether the plan is feasible.
(8) To show the results. Teachers organize for students to evaluate and exchange their works. Groups learn from each other and share their own experience. At the same time, teachers should comment on and guide students' works.
(9) To reflect and summarize. Teachers guide students to reflect on their gains in knowledge and skills, and also guide students to reflect and summarize the learning process, learning attitude, learning experience, and learning methods [42].
(10) To create new problems. Based on the feedback from teachers, mutual communication between students and self-reflection, students rethink schemes, generate new problems, and think through whether the schemes can be improved to produce greater effects. According to the results of the discussion, teachers reestablish the evaluation criteria, which brings new challenges. Students understand the challenge again, enter the cycle of inquiry, and iterate the design until they get a satisfactory solution.

2.3.4. Teaching Environment

Teachers and schools should provide students with abundant hardware resources and suitable learning spaces, and provide students with various forms of tool support. Since there are many contents that need to be practiced in order to truly master them, it is necessary to create conditions for school-enterprise cooperation so that students have the opportunity to go to production sites to learn.

3. Research on the Impact of Design-Based Learning Education and Outcome-Based Education in Industrial Engineering

Basic industrial engineering is a very important course for the major of industrial engineering, and it is also an introductory course for industrial engineering. It has the characteristics of strong comprehensiveness, strong practicality, and a close connection of knowledge points [44]. However, due to the influence of the traditional teaching method, the teaching mode and teaching effect of basic industrial engineering are not ideal, the initiative of students in class is not fully utilized, and students have a poor understanding of knowledge points and practical application ability, so they cannot be trained with the ability to analyze and solve problems. Therefore, the industrial engineering course teaching method based on design-based learning (DBL) education mentioned in Section 2.3 was applied to the teaching of basic industrial engineering where the focus is to cultivate students' comprehensive use of knowledge, independent analysis and problem solving, and innovation, etc.

To explore the impact of design-based learning (DBL) education and to familiarize teachers and students with the process, a subject was designed for the on-site "5S management" module in "Basic Industrial Engineering", to improve the storage and turnover protection of sheet metal parts in a company's sheet metal warehouse, and improve the on-site 5S management level and turnover efficiency. At the same time, guided by the concept of outcome-based education (OBE), students are allowed to learn with their goals in order to obtain the final learning outcomes that students in basic industrial engineering classes need to achieve. Below are the specific characteristics of the subject.

The theme of this subject is the on-site 5S management learning based on DBL. In the subject, students are the center of teaching activities, completing theoretical and practical learning independently, and teachers mainly play a guiding role. The selection standard of the subject is to select the packaging and turnover of sheet metal parts in an enterprise. The enterprise organically adds workshop, painting workshop, and sheet metal warehouse, and a large number of sheet metal parts circulate among these three parts every day. The subject meets four standards, as shown in Table 1.

Table 1. Four standards of the subject.

	Standards	Expand the Description
1	Meets the learning objectives of design-based learning	The subject has a greater degree of freedom, and students can freely use the design plan and cultivate their independent innovation ability
2	Conforms to the principle of "three-presentism" of industrial engineering	Students learn 5S on site
3	A practical hands-on subject	Students can directly participate in the practice
4	Conforms to the principles of outcome-based education	Students take the initiative to complete learning tasks, and teachers play a guiding and auxiliary role

Moreover, the subject lasted for two weeks and the driving problem of this topic was: how to improve the efficiency of sheet metal packaging and turnover protection of an enterprise under the premise of design-based learning? This subject adopted the method of school enterprise cooperation, and invited experts from the technical department of the enterprise to guide the subject. The learning scaffolding of the subject was that teachers provide students with relevant books and materials, and enterprises provide students with conditions and tools for on-site improvement. In addition, the curriculum evaluation standard was to focus on the cultivation of students' comprehensive ability. The topics were student-led. Students conducted problem solving, the collection of data, problem analysis, and schemes design independently.

This subject emphasized the autonomy of students by:

(a) Students going to the site to obtain relevant sheet metal packaging and turnover protection status. Figure 3 shows the photos collected by students on site. It can be seen from the on-site pictures that the parts are placed at random and easy to scratch during transportation, and it is not easy to count the quantity.

(b) Analyzing the key factors that cause problems with the existing packaging and turnover protection. Figure 4 shows the analysis conducted by the students using the fishbone diagram; the red boxes are the main factors. The students analyzed the reasons for the nonstandard packaging of sheet metal parts from five aspects of humans, machines, materials, methods, and the environment, and obtained the key factors leading to the packaging problems, which provided the direction for improving the design of the scheme.

(c) Students designing solutions to improve existing problems.

Figure 3. Photos collected by students on site.

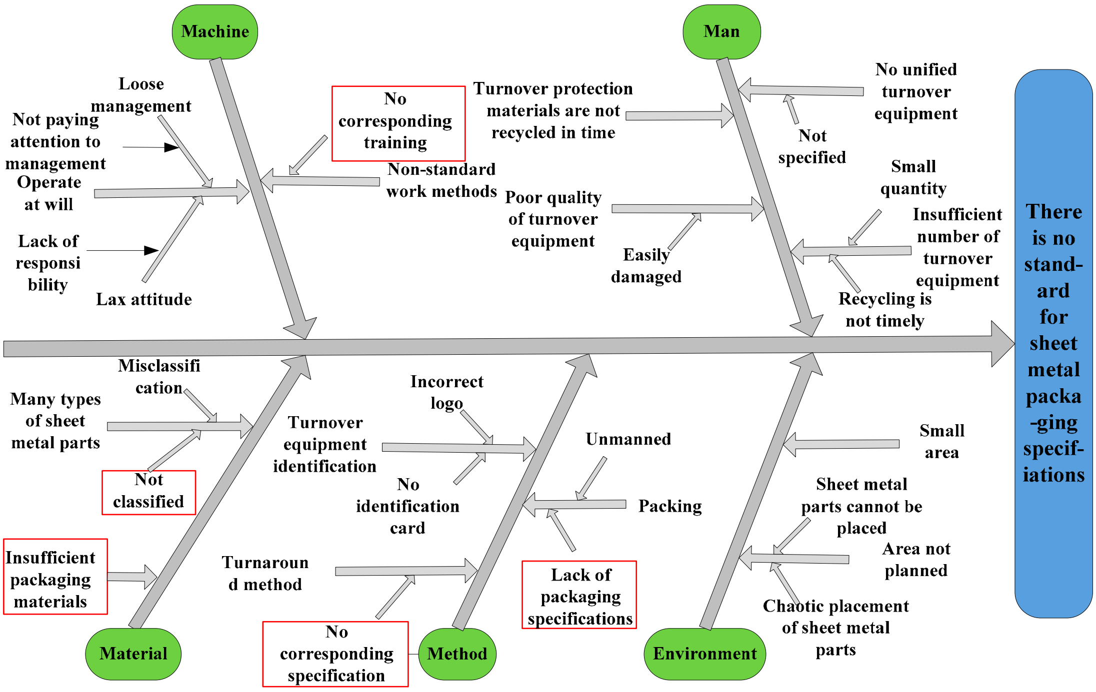

Figure 4. Fishbone Diagram.

We interviewed each student for about 15 minutes after every class. The interview content included two aspects. One was about design-based learning: (1) what are the advantages of design-based learning compared with a traditional classroom? (2) What abilities have been significantly exercised and improved? (3) In the process of design-based learning, what tasks are more challenging? (4) What processes or experiences need to be improved? Is there a good way to improve them? (5) Which do you prefer between traditional teaching and design-based learning teaching? Why? The second is about outcome-based education: (1) through this study, what goals do you think should be achieved? Did you achieve these goals? (2) What abilities have been significantly exercised and improved? (3) After the basic industrial engineering course is over, what do you hope to gain? Finally, the interview results were sorted out and the following results were obtained.

The design-based learning (DBL) and the outcome-based education (OBE) concept were applied to the teaching of basic industrial engineering, which effectively improves students' learning interest and learning efficiency, and the number of people attending the lectures attentively increased. Students now have a greater interest in textbook knowledge and this motivates them to actively learn and think. The learning model is no longer to listen to lectures and complete homework after class, which creates more room for students to play.

The application of design-based learning approach has effectively cultivated students' innovative thinking and manual brain skills. They can design feasible plans to complete tasks by themselves. Students no longer rely solely on teachers to "instill" knowledge, but learn spontaneously, and combine new and old knowledge. In traditional classrooms, there is some difficulty in understanding knowledge by only relying on classroom explanations and simple experiments, while through design-based learning (DBL), students have more opportunities to practice or go to the production site to observe, thereby improving their practical ability.

DBL is conducive to training students' teamwork ability. The content of design-based learning (DBL) is more challenging for students, but they can work in teams to complete the tasks. The team members can divide the work reasonably and have clear responsibilities to complete the task smoothly.

The students also said that the experience of "making the master" in this class entirely by themselves is very good, but it also brings more difficulty and requires more energy. At the same time, it is necessary to change the learning mode from the passive acceptance of knowledge.

In addition, the students pointed out that in the learning process, some people's sense of participation is not very high, which requires a clearer division of labor and evaluation criteria. In addition to the evaluation and scoring of each group, the individual performance should also be evaluated. Members of the group could evaluate each other to urge everyone to actively complete tasks.

In terms of learning objectives, students hoped to have a better understanding of how textbook theoretical knowledge can be applied to practical work after the completion of the course. Students said that they can have a more thorough understanding of knowledge in an enterprise than in the classroom and can lay a good foundation for their future work there.

4. Teaching Case Design

4.1. Teaching Design

The teaching activity designed by Fortus of the University of Michigan consists of three units, namely, buildings in harsh environment, safe batteries, and safe mobile phones that are conducive to the environment. The researchers tracked 92 students' project-based learning in the three units, and compared and analyzed the test data before and after using SPSS software. It was found that for both excellent and ordinary students, design-based learning has achieved better results than other teaching methods in learning scientific concepts, and students can better apply these scientific concepts through such teaching. This research of professor Fortus provides ideas for the teaching design process of this paper [12].

We took "Assembly Production Line Balance" as an example to illustrate the teaching process of design-based learning and verified its application effect. In an assembly production line site, there may be a large gap in the operating time of the operators at each station of the production line. This results in an imbalance in the production line and a longer production cycle, the on-site 5S not meeting the specifications, and the waste of the operator's action of the operation causing the work time to increase and the work difficulty increasing.

The design problem is: design a plan to make the cycle time of each station of the assembly line the shortest and consistent, so that it can achieve the balance of the production line, improve the waste of operators' work movements, and improve the 5S problem that exists on the spot. There are many knowledge points involved in this problem, including production beats, line balance, operation analysis, motion analysis, on-site5S, etc.

In order to verify the effect of design-based learning (DBL) applications, experimental classes (CL1 class, 30 students) and control classes (CL2 class, 30 students) were set up. With CL1 classes based on a design-based learning and teaching method, with students in the leading role, and teachers playing a guiding and helping role, we divided students into groups, 5-6 people in each group. According to the interview for the results of the above-mentioned "sheet metal parts turnover protection" subject, before the project starts, we formulated knowledge goals, ability goals, and quality goals, and designed the subject based on these goals. Each group of students had a clear division of labor, while the teacher gave necessary guidance and help when the project was difficult to progress. The CL2 class followed the traditional teaching method, while the learning method was mainly for teachers to use PPT to explain in class. After the course was completed, students were also allowed to complete the topic of "assembly line production balance" after class. Below are the specific courses of CL1:

The basic principle of the subject is that the main body of the design-based learning classroom is the students, and the teachers propose challenging tasks, such as increasing the production efficiency of a company's assembly line by 30%. In terms of learning autonomy, teachers require students to collect data based on task requirements, discuss in groups, design plans, implement plans, make improvements to plans, and to make sure their plans are evaluated jointly by teachers and business personnel.

The criteria of selecting the subject was the topic of "Assembly Production Line Balance" which covers a large number of knowledge points in basic industrial engineering, including chapters such as program analysis, operation analysis, motion analysis, stopwatch time research, field management methods, etc. In the process of project implementation, students were able to integrate the knowledge of each chapter, and continue to learn new knowledge by simply mastering existing knowledge. At the same time, the content of "assembly line balance" is also a very important knowledge point in industrial engineering, as many industrial engineering students are exposed to line balance in their jobs after getting employed, laying the foundation for their future employment.

The duration of the project was two months. As the topic continued, students could master the knowledge points in basic industrial engineering. The driving question of this project was: how an enterprise's assembly line can be improved to achieve balance while improving productivity?

What is more, in the process of completing tasks, students must master the knowledge points of program analysis, operation analysis, motion analysis, stopwatch time research, and field management in basic industrial engineering, while it was also necessary to master the seven major wastes in lean production, just-in-time production, etc. The completion of the topic was not a single knowledge point or a single course of study.

Furthermore, the learning framework of this project was as follows:

(a) At the beginning of the project, teachers explained the knowledge points in basic industrial engineering, so that students have a basic understanding and mastery of the course knowledge, and are familiar with the use of various methods and tools in the topic. During the implementation of the design plan, teachers provided necessary assistance according to the needs of students, such as images and photos of the production site. They also led students to the production site to collect the required information by themselves, taught the application methods and drawing methods of program analysis charts, and provided the necessary tools for the implementation of the program, such as a tape measure, stopwatch, etc. In addition, teachers guided the students to observe the key points on the spot, focused on the objects of improvement, and discussed the feasibility of the design scheme with the team members. They evaluated the design results and solved the problems and difficulties in the design study, and the students revised and optimized the design again according to the guidance of the teacher.

(b) Teachers put forward requirements for this subject, combined with the concept of outcome-based education (OBE), guided by the expected final learning results of the students, asked for the student's final achievement, and clarified the goals. For example, the efficiency of the production line should be increased by 30%, the waste in the field must be identified and reduced, the work of the operators should conform to the principle of action economy, and the students should master and apply the content of basic industrial engineering at the end of the project.

(c) School-enterprise cooperation to provide improvement sites.

Figure 5 is a picture of the operation site of a company visited by students.

Figure 5. The operation site of a company.

The most important thing in this activity is the cultivation of students' personal ability. Students had enough time to explore knowledge and design schemes in the context of the subject. In addition, this project emphasized students' autonomy and initiative: (a) Students understand the overall idea of "production line balance" and improvement of the subject through their teacher's explanation and self-checking of relevant materials. (b) Students visited the assembly production line site, conducted on-site observations, calculated working hours, obtained data, and found waste at the production site. (c) Students designed and elaborated their own schemes by themselves. (d) After the scheme design was completed, students tried to improve on the spot, and invited teachers and business experts to put forward opinions and suggestions on the improvement effect. These suggestions also stimulated students to modify their own design plans.

4.2. Data Collection

In order to obtain the learning effect of design-based learning (DBL) and outcome-based education (OBE), we interviewed participants. In fact, before the beginning of the course, we had an effective communication with students and explained to them that this was a very interesting teaching experiment, so teachers and students should participate in it together to explore the effect of a new teaching method. The interviewees included five teachers from the Department of Industrial Engineering and students in the experimental and control classes. Interview questions are provided in Appendix A Table A1.

The data sources of this study were as follows: 1. Questionnaire and participants (Table A1): to interview teachers and students' views on the application of design-based learning and outcome-based education in teaching, so as to get more results about the teaching effect. 2. Interview answers to the second question in the questionnaire and participants form (Table A2): from the six aspects of students' classroom enthusiasm, which are students' classroom participation, teacher-student interaction, classroom atmosphere, teachers' lecture attraction, and students' knowledge acceptance, we could judge that the "DBL + OBE" teaching method is obviously better than the traditional curriculum. 3. The answer to the third interview question in the questionnaire and participants form (Table A3): which personal abilities of students have been improved through design-based learning. 4. Design log (Table A4): this was used to record students' learning process, including problem analysis, learning of new knowledge, problem solving strategy, design schemes, modification scheme, etc. 5. Students' personal evaluation form (Table A5) was used for students' self-evaluation.

5. Results and Discussion

5.1. Results

Teachers and students both stated that the learning effect of the experimental class students was significantly better than that of the control class. The application of design-based learning (DBL) made the classroom atmosphere more active and relaxed. There was a significant increase in the number of teacher-student interactions. The "interaction" here was no longer just the interaction of "teacher asking and students to answer" in traditional classrooms. It was more about students discovering and finding questions, actively thinking, and discussing their opinions with teachers. Teachers also shared their opinions with students, allowing students to learn and think independently, and at the same time, teachers and students learned from each other.

The teachers participating in this subject listened to a lesson in the design stage of the experimental class and the control class, respectively, and counted the number of teacher-student interactions. The number of teacher-student interactions referred to the number of times in the process of subject design that: (1) teachers asked questions and students actively answered them; (2) students found problems and asked teachers for guidance; (3) teachers and students discussed and analyzed problems together. According to teachers' statistics, there were 72 interactions between students and teachers in the experimental class and 35 interactions between students and teachers in the control class. Students had a higher level of classroom participation, and they were more active in learning and exploring instead of passively accepting knowledge. The students said that the design-based learning (DBL) teaching method was out of this world, the number of people playing on mobile phones or sleeping in class was significantly reduced, and their understanding and acceptance of knowledge was significantly improved. Therefore, regarding the answer to the second interview questions, teachers preferred A, B, C, and D, and students preferred B, D, E, and F, as shown in Figure 6.

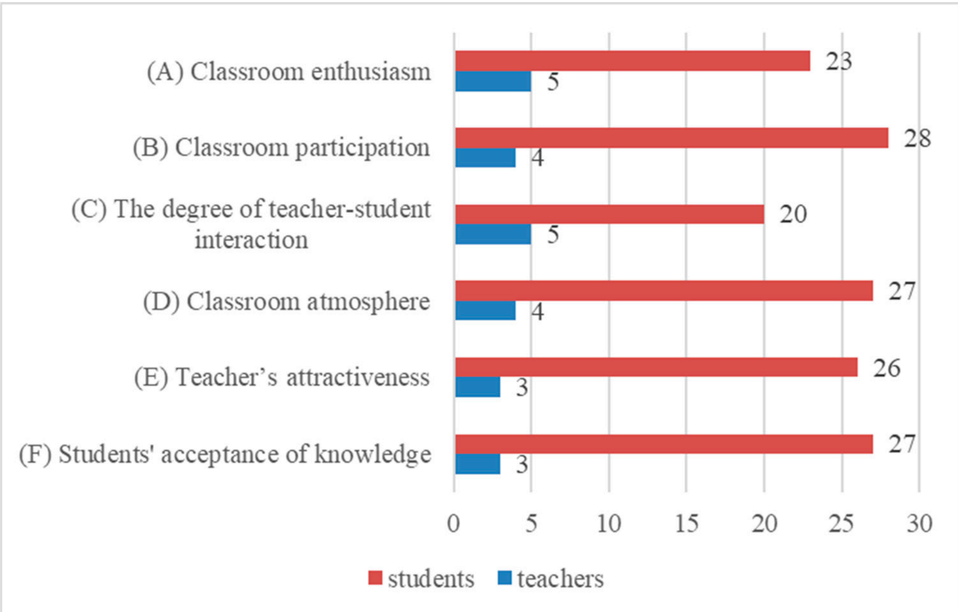

Figure 6. Results of the effects on application of interviews.

As for the results of the interview about ability improvement, teachers preferred A, B, C, and E, and students preferred C, D, E, and F, as shown in Figure 7. At the same time, the teachers said that the application of design-based learning (DBL) had made their teaching design more colorful. Teachers had also begun to pay attention to the innovation and attractiveness of the classroom, and implemented personalized teaching. The classroom was no longer boring, and teachers had learned a lot from it, which was not possible in traditional classrooms.

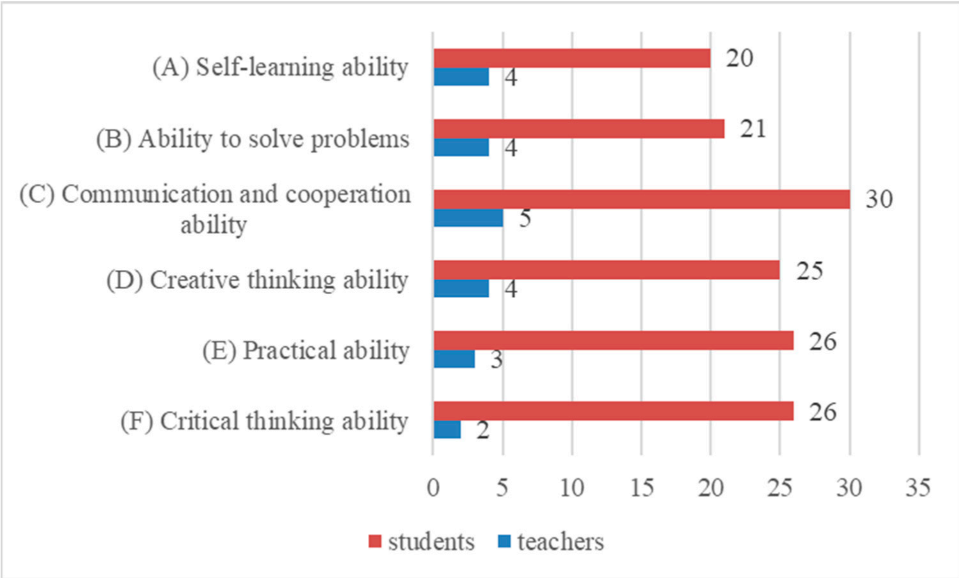

Figure 7. Results of the ability improvement interview.

As for the application of outcome-based education (OBE) concepts, the experimental class' students said they were braver in expressing their opinions and had better language skills than in traditional courses; thanks to teachers' encouragement and trust, they were more confident in the classroom, and were willing to take the initiative to find resources to solve problems when encountering difficulties, unlike in the traditional classroom. Teachers said that the application of the outcome-based education (OBE) concept had made teacher-student relationships more harmonious, students were more willing to communicate their ideas with teachers actively, and the classroom had become more open and free. Teachers discovered different forms of assistance for students, and used different training methods to guide each student to "success". They often encouraged students by saying "you must learn to crawl before you work".

Regarding the achievement of learning goals, both teachers and experimental class students stated that the goal of increasing the production efficiency of the assembly line by 30% had been achieved. However, in terms of personal abilities, such as creative thinking ability, practical ability, etc., which could not be quantified, they could only rely on subjective evaluation and it was impossible to determine whether students had achieved their objectives and to what extent. This is also where the teaching concept of "DBL+OBE" should be improved in future teaching. Teachers asked whether it is possible to develop or find a tool to evaluate students' personal abilities quantitatively.

As for the promotion and application of the "DBL+OBE" teaching method, both teachers and students said that the course experience was good and the effect was very significant, which could be extended to the teaching of other industrial engineering courses. However, it was necessary to "teach students according to their abilities" and made appropriate adjustments to the teaching method according to the characteristics of different courses and students.

Five teachers scored the performance of the five groups of students in the experimental class and the five groups of students in the control class. The maximum score was five, comprehensive students' mutual evaluation scores, all the scores were anonymous. Excluding extreme values, the average score of the control class was 3.5 and the experimental class was 4.2. Figure 8 shows the scores of each group in the experimental and the control class.

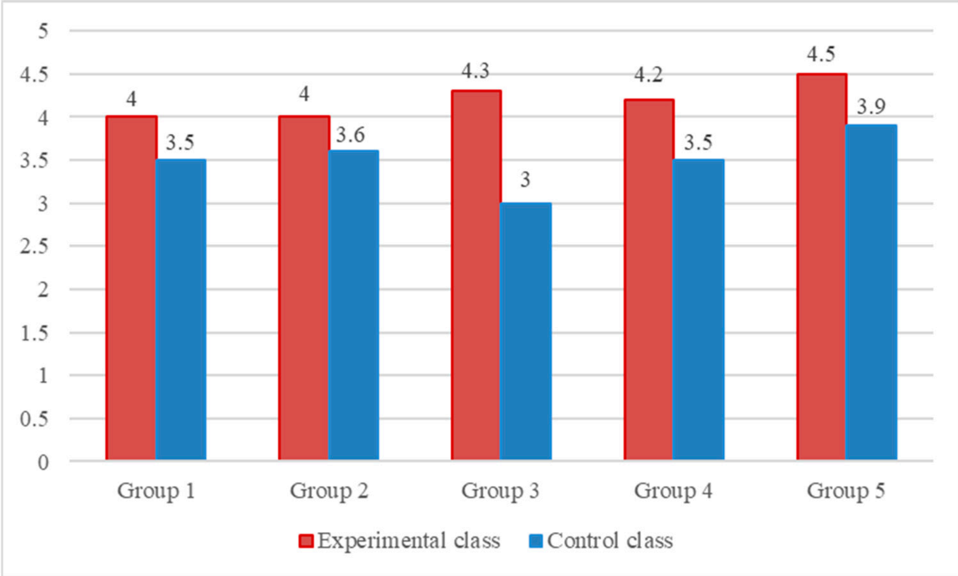

Figure 8. The scores of each group in the experimental class and the control class.

After the interview, we let the students in the two classes conduct self-diagnosis based on their performance and gains. Table A3 is the student self-diagnosis form. The full score was 10 points and the students conduct self-diagnosis. According to the scores of the experimental and the control class, each class took the average. Figure 9 was a radar chart of student self-diagnosis score distribution.

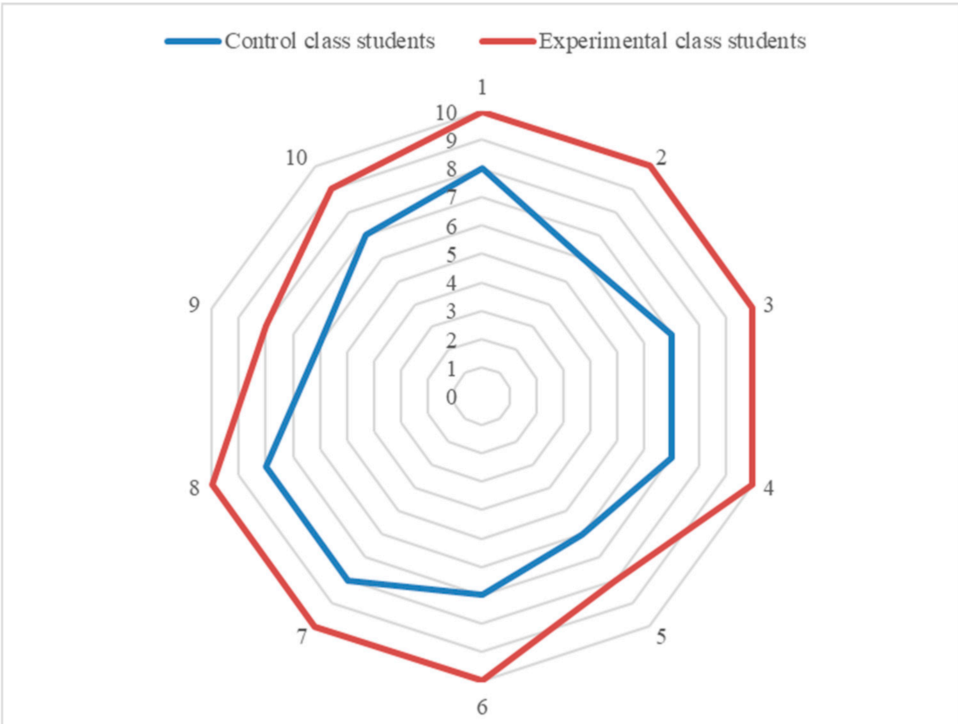

Figure 9. Student self-diagnosis score distribution.

5.2. Discussion

The questionnaires showed that the teachers and students participating in this subject thought that the teaching effect of applying "DBL + OBE" in basic industrial engineering teaching was much better than that of traditional courses. They agreed that it is important to pay attention to the cultivation of practical ability and innovation ability in the courses. On the other hand, we applied the "DBL + OBE" method to the typical project activities of basic industrial engineering, and the results showed that this new teaching method is practical in the existing teaching programs.

Furthermore, the questionnaires showed that in this research, more than half of the students had a positive attitude towards this new teaching method, and more students agreed to extend this method to other courses of industrial engineering. In the area of ability training, the investigation showed that the students in the experimental class knew better which abilities they had successfully obtained and which abilities they should pay more attention to. The reason for any differences may be that the students in the experimental class were active learners, while the students in the control class were passive participants in educational activities. Active learners may prefer the "DBL + OBE" method and be more aware of its advantages in developing individual abilities.

Previous studies [45] established a framework of design-based learning, and found the advantages of design-based learning method in improving students' sustainable development ability. Our research in this paper expands the previous research and shows the advantages of the DBL method combined with the OBE method in improving students' practical ability, autonomous learning ability and innovation ability, etc. By comparing the results of the experimental class and the control class, and through the analysis of the above interview data, we found that the students in the experimental class were more outstanding in their practical ability, autonomous learning ability, language expression ability, and problem finding ability. The above analysis of interview data showed that the DBL + OBE method was more conducive to the cultivation of students' comprehensive abilities and the cultivation of "innovative talents" that are needed in the new era.

6. Conclusions

It is important to improve the teaching level of the Department of Industrial Engineering, cultivate the industrial engineering talents needed by society in the new era, and improve students' independent learning ability, practical ability, innovation ability, etc. This research first discussed the reforms of teaching methods made by other scholars and presented a new teaching method of the "design-based learning (DBL) and outcome-based education (OBE) concept". This new method had the purpose of exploring the application effect of this teaching method and familiarizing teachers and students with this teaching process. A subject of "Improvement of Sheet Metal Turnover Protection" was designed. Subsequently, in order to complete the study of the "Basic Industrial Engineering" course, and to verify the application effect of the "DBL + OBE " teaching method, we designed a "Assembly Line Balance" topic and set up experimental class and control class. Finally, through interviews with teachers and students, it was preliminarily proven that this teaching method has a certain effect.

The limitations of this study are obvious. This study focuses on the specific field of industrial engineering. It does not explore the impact of DBL and OBE teaching methods in other engineering or education fields, such as mechanical engineering. Therefore, the practicability of this method in these areas needs to be further studied. Moreover, because it is still in the exploratory stage and the application was not proficient, the duration of the subject was found to be too long. In addition, it is important to use more teaching experiments to prove the effectiveness of the method proposed in this article, and it is necessary to prove whether the proposed teaching method in this article can be applied to other courses, and if so, what adjustments should be made to facilitate this. Furthermore, since the evaluation of the improvement of students' abilities is mainly a subjective judgment, whether it is possible to develop or find a method or tool to quantify students' abilities also needs to be explored. In future teaching, we should learn from the theories and experiences formed in the practice of Design-Based Learning (DBL) and Outcome-Based Education (OBE) at home and abroad and further explore and construct learning models that are in line with the reality of education in China. In the future, we will apply a combination of DBL and OBE to other engineering courses, such as mechanical engineering and civil engineering. In addition, we can further discuss and study the methodology of the proposed teaching method.

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Appendix A

Table A1. Questionnaire and participants.

Interview Direction	Questions	Participants
Design-Based Learning	1. Is the classroom experience of design-based learning better than traditional courses?	Teachers, experimental class students, control class students
	2. What aspects are better than traditional courses? (Please select four items and below) A. Students' classroom enthusiasm B. Student classroom participation C. The degree of teacher-student interaction D. Classroom atmosphere E. Teacher's attractiveness F. Students' acceptance of knowledge	Teachers, experimental class students
	3. What abilities have been significantly improved by the teaching of design-based learning? A. Self-learning ability B. Ability to solve problems C. Communication and cooperation ability D. Creative thinking ability E. Practical ability F. Critical thinking skills	Teachers, experimental class students
	4. What is the obvious difference between using design-based learning teaching and traditional teaching?	Teachers
Outcome-Based Education	5. Is the application of outcome-based education concepts better than traditional courses?	Teachers, experimental class students, control class students
	6. Compared with traditional classrooms, what are the obvious changes in teachers' teaching and students' learning methods? (Please select four items and below) A. Students have the courage to express their opinions B. Language organization and expression ability C. Student confidence in classroom D. Students' initiative to find resources to solve problems E. Teachers-students relationship F. Teachers' teaching initiative	Teachers, experimental class students, control class students
	7. Did you achieve the goal set at the beginning of the course?	Experimental class students
	8. What goals have been achieved? Which goals were not achieved? What is the reason for the failure?	Experimental class students

Table A1. *Cont.*

Interview Direction	Questions	Participants
learning experience	9. Can the "DBL+OBE" teaching method be applied to other courses in industrial engineering?	Teachers
	10. What are the shortcomings of the current "DBL+OBE" teaching method?	Teachers, experimental class students
	11. Is the teamwork of students in the experimental class higher than in the control class?	Teachers, experimental class students, control class students
	12. Compared with the traditional classroom, are the experimental class students more willing to learn actively?	Teachers, experimental class students, control class students

Table A2. Interview answer to the second question in the questionnaire and participants form.

	Teachers (5 Persons in Total)	Students (30 Persons in Total)
(A) Classroom enthusiasm	5	23
(B) Classroom participation	4	28
(C) The degree of teacher-student interaction	5	20
(D) Classroom atmosphere	4	27
(E) Teacher's attractiveness	3	26
(F) Students' acceptance of knowledge	3	27

Table A3. Interview answer to the three question in the questionnaire and participants form.

	Teachers (5 Persons in Total)	Students (30 Persons in Total)
(A) Self-learning ability	4	20
(B) Ability to solve problems	4	21
(C) Communication and cooperation ability	5	30
(D) Creative thinking ability	4	25
(E) Practical ability	3	26
(F) Critical thinking ability	2	26

Table A4. Design log.

Research Topics		
Team Members:	**Class:**	**Group Number:**
What is the goal of the design?		
What are the methods used in the design?		
Problems in design and Solutions?		
What goals have the final design achieved and what results have been achieved?		
What courses and knowledge are used in this design?		
What have you gained in this design?		

Table A5. Student Self-diagnosis Form.

No	Evaluation Item	Control Class Students	Experimental Class Students
1	Is the design plan appropriate?	8	10
2	Is the phenomenon clear?	6	10
3	Is the goal setting reasonable?	7	10
4	The effect of the formulation and implementation of the design plan?	7	10
5	Satisfaction with improvement results?	6	8
6	Is there a sense of improvement?	7	10
7	Has classroom participation and satisfaction improved?	8	10
8	Is learning autonomy improved?	8	10
9	Has the practical ability and creative thinking ability improved?	6	8
10	Has the teamwork and communication skills of team members improved?	7	9
	Total	70	95

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