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STEM Teaching for the Internet of Things Maker Course: A Teaching Model Based on the Iterative Loop

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Received: 15 June 2020; Accepted: 15 July 2020; Published: 17 July 2020

Abstract: As the key technology for 5G applications in the future, the Internet of Things (IoT) is developing rapidly, and the demand for the cultivation of engineering talents in the IoT is also expanding. The rise of maker education has brought new teaching inspiration for cultivating innovative technical talents in the IoT. In the IoT maker course, teaching problems include the lack of adequate teaching models, emphasis on products but less emphasis on theory, and letting students imitate practice. Focusing on these problems, this paper proposes a new Science, Technology, Engineering, and Mathematics (STEM) teaching model called Propose, Guide, Design, Comment, Implement, Display and Evaluate (PGDCIDE) for the IoT maker course. The PGDCIDE teaching model is based on STEM teaching and Kolodner's design-based scientific inquiry learning cycle model, and realizes the combination of "theory, practice, and innovation." Finally, this paper designs the IoT maker course to practice the PGDCIDE model. The practical results indicate that students significantly improved their emotional level, knowledge level, and innovation level after studying the course. Therefore, the PGDCIDE teaching model proposed in this paper can improve the effectiveness of the IoT maker course teaching and is conducive to the cultivation of students' sustainable ability in engineering education. It has reference significance for the application of maker courses in engineering education practice.

Keywords: internet of things; maker course; STEM teaching; curriculum implementation

1. Introduction

The launch of global 5G has brought new driving forces to the Internet of Things (IoT) industry [1], and countries around the world have already adopted the IoT as their national strategic industry. The IoT creates wealth in many industries [2], and by 2025, the IoT will generate a potential value of from USD 3.9 trillion to USD 11.1 trillion in nine industries, including manufacturing, healthcare, retail, and transportation [3]. The innovation of IoT technology has promoted the growth of the social economy and has a transformative impact on society. In the final analysis, the competition of IoT technology between countries is the competition of technological innovation talents [4]. Therefore, universities in the whole world have started to build new IoT engineering majors and explore new curriculum teaching. The engineering education advocated by the Conceive, Design, Implement, Operate (CDIO) model needs to adjust the talent training mode according to the needs of the industrial production field. The CDIO model has far-reaching significance in engineering education and the cultivation of engineering talent in the world, which means that engineering education has entered the engineering practice paradigm [5,6]. Affected by the reform of engineering education, scholars from various countries have focused on engineering practice for the IoT engineering major and developed different curriculum design forms.

Page, T. [7] proposed that the IoT should be included in the industrial design curriculum. He, J. et al. [8] believe that undergraduate course learning, the learning framework of the IoT, and experimental projects should be integrated into the STEM core curriculum. Raikar, M.M. et al. [9] proposed taking the IoT course as an open elective course and adopting an activity-based teaching method. The Indian government initiated a course project on "smart sensors and the Internet of Things" [10], and educational institutions are also committed to using the IoT technology to stimulate students' learning interest [11].

China has made the IoT major a "new engineering" major, researched IoT courses, and created diverse courses [12–17]. The CDIO engineering education advocated by the International Initiative is to provide students with an education that emphasizes engineering fundamentals, which are set in the context of concept-design-implementation-operation (CDIO) actual systems and products [18]. The reform of engineering education in the CDIO model is like the purposeful development design and final realization of products advocated for in maker education. Maker education is an educational model that emphasizes creation and practice. Therefore, the construction of maker courses can enrich the teaching forms of engineering education and cultivate the sustainable development ability of technical engineering talents [19,20], such as practical ability, innovation ability, and ability to solve practical problems. Moreover, Zhiting, Z. et al. [21,22] proposed that open-source hardware such as Arduino and Raspberry Pi injects new vitality into the maker course, which is beneficial in promoting the practice of engineering education.

However, the current maker course offered by the IoT major places too much emphasis on making products, focusing on practice, and ignoring the basics of theoretical knowledge learning. These are inconsistent with the engineering education training objectives listed in the CDIO syllabus, including fundamental professional theories and practical operation ability [23,24]. Many teachers still use the past imitation experiment teaching model in the maker course. The teaching process lacks innovation and design, which is not suitable for cultivating the learner's innovative spirit and creativity [25–29]. Therefore, the advantages of the application of maker courses in engineering education are reflected in open innovation, exploration experience, and let students learn practical skills in the process of making products. The disadvantage of this method is that it pays attention to the production of products in practice and ignores the learning of theoretical knowledge, and lacks a useful teaching model.

From the perspective of interdisciplinary innovation, "Engineering (E)" in science, technology, engineering and mathematics (STEM) is a "bridge" that connects the knowledge of scientific, mathematical, and technical disciplines. The integration of STEM education and maker education will comprehensively promote the cultivation of students' innovative ability and high-level thinking ability, and make up for the lack of theoretical knowledge learning in the maker course [30]. Therefore, based on the current situation of IoT maker courses and the goal of cultivating innovative talents, this paper proposes a teaching model based on the STEM concept. This model's innovation is to integrate theory guidance and program comments into the four core steps of traditional STEM teaching to form an integration "theory, practice, and innovation." Finally, the teaching model was applied to an IoT maker course, and the effectiveness was proved through practice.

2. STEM Teaching Model Research

2.1. The Feasibility of Introducing STEM Teaching into IoT Maker Course

Maker education and STEM education have certain commonalities. The educational goals of both include the cultivation of innovative talents [31], the educational concepts are integrated with Dewey's "learning by doing", and teaching activities can be project-based learning activities [32,33]. However, the maker course's teaching is more like the Western maker culture, and it is biased towards the output of "physical works". It lacks the construction of students' theoretical knowledge. Therefore, several reasons for introducing the STEM concept into the IoT maker course are as follows:

(1) The "interdisciplinary" and "generative" of STEM content [34] are compatible with the characteristics of the interdisciplinary subject of the IoT major and the materialized output of the maker course;
(2) The "inquiry" and "engineering" of STEM implementation [34] are highly consistent with the implementation of the maker courses of the IoT;
(3) The "iterative" and "experience" of the STEM process [34] can be reflected in the continuous integration of learners with their new and old experiences in the process of implementing IoT maker projects to achieve the development of cognitive experience;
(4) The "divergence" and "innovation" of STEM cultivation [34] are consistent with the cultivation concept of IoT maker courses, which meets the needs of the national society for the cultivation of talents in this major.

In summary, based on the STEM concept, this paper will study the STEM teaching model applicable to the IoT maker course and provide a new teaching model for the implementation of maker courses.

2.2. The Core Steps to Research STEM Teaching Model

The IoT maker course is mainly teaching based on engineering projects. According to the National Academy of Engineering design process, Lidan, H. et al. proposed a STEM teaching model for creativity training [35]. Xi, C. et al. proposed the design and implementation of STEM curriculum based on engineering design [36]. Xingzhu, P. et al. proposed the "Scaffolding+" STEM teaching model [37]. Yongmei, C. et al. proposed the design of teaching activities based on the STEM education concept [38]. Rong, G. et al. proposed a STEM teaching model for secondary vocational schools based on the engineering design process [39].

The four core steps of the STEM teaching model based on engineering design can be summarized by studying these models, as shown in Figure 1. These are to "Propose Questions", "Design Plans", "Implement Plans", and "Display and Evaluate".

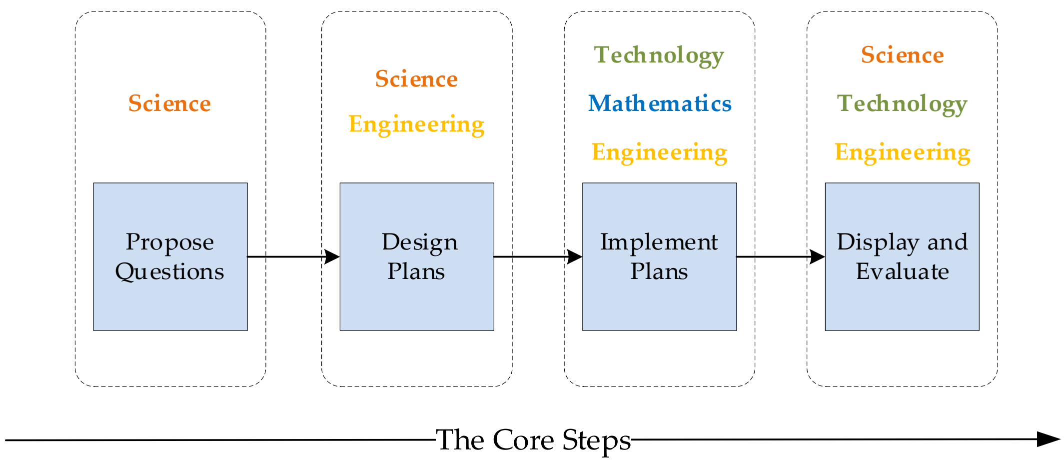

Figure 1. Four core steps of science, technology, engineering and mathematics (STEM) teaching model.

2.3. The Propose Design Guide Comment Implement Display Evaluate (PGDCIDE) Model Based on the Iterative Loop for STEM Teaching

Kolodner believes that design development requires multiple cycles to complete. Therefore, he proposed that the design-based scientific inquiry learning cycle model has two cycles, as shown in Figure 2. One is "design-redesign", and the other is "investigation-exploration." The two loops iterate and merge. After discovering problems, learners collect data to design solutions, implement experiments, share the results with others, find deficiencies and then conduct iterative experiments or investigations.

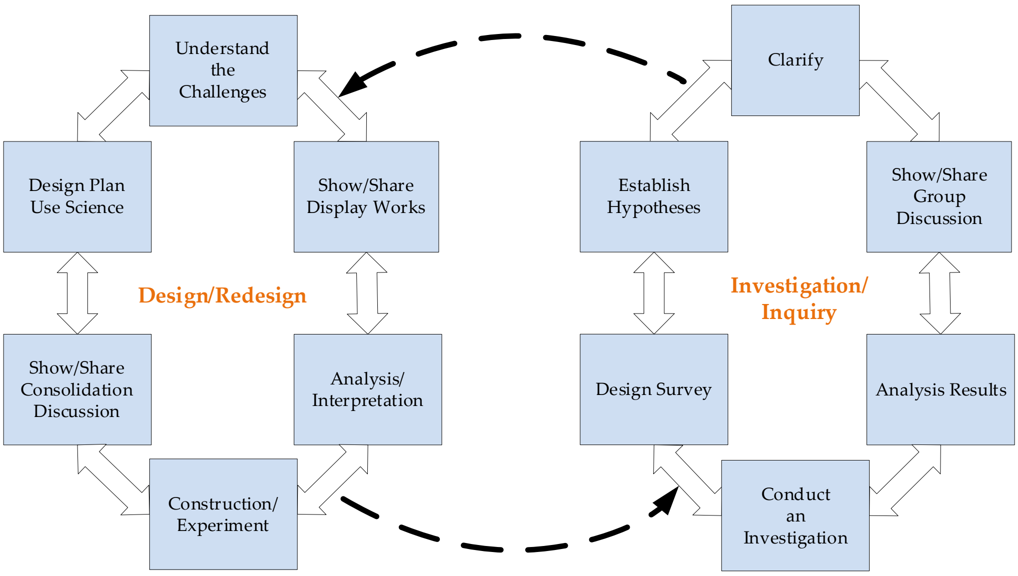

Figure 2. Double-loop learning inquiry model based on design.

To solve the problem, learners do not pay much attention to theoretical knowledge and the lack of innovative exploration of the design and implementation of solutions in the IoT maker courses. This paper proposes a new STEM teaching model, PGDCIDE, for IoT maker courses based on Kolodner's design-based scientific inquiry learning cycle model [40].

The PGDCIDE model adds "Guide Theory" and "Comment Plans" to the core steps of the STEM teaching model and forms an iterative cycle among "Guide Theory," "Design Plans," and "Comment Plans," as shown in Figure 3.

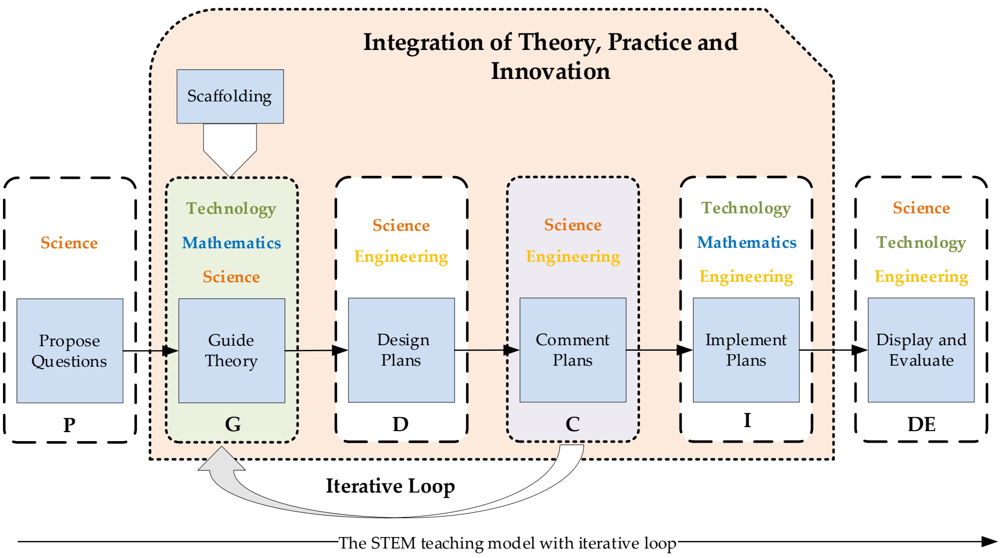

Figure 3. The propose guide design comment implement display and evaluate (PGDCIDE) model.

"Guide Theory" is the next step in "Propose Questions." On the one hand, "Guide Theory" can make up for the lack of basic theoretical knowledge in the previous maker courses. On the other hand, it can promote learners' independent exploration ability and stimulate an interest in learning. Teachers put up scaffolding for learners to independently learn theoretical knowledge based on the questions raised. After the learners have mastered the theoretical knowledge of the problem to be solved, they have a more definite direction in designing the solution.

"Comment Plans" is the next step in "Design Plans." By evaluating the feasibility and scientificity of the students' design plan, teachers can understand the learners' mastery of the previous theoretical knowledge. In the process of "Comment Plans", students can generate different innovative ideas, thereby promoting communication and learning among learners, and designing the optimal plan.

When the learner finds a deficiency or encounters a new challenge, and needs to add relevant theoretical knowledge on time, he returns to "Guide Theory" again, and inquires and searches the information on the scaffolding built by the teacher, and then modifies the plan again until the plan is optimized. In the iterative cycle of "Guide Theory" to "Comment Plans," learners can supplement the extensive theoretical knowledge, improve problem-solving ability, and stimulate the awareness of innovation.

(1) Propose Questions (P)

The STEM teaching implementation model focuses on the problems that need to be solved from the creation of real-life scenarios. Therefore, teachers need to design a situation story around the teaching content to attract students' attention, and then ask questions set in advance. The problems in the scenario need to be feasible, novel, and creative, and the difficulty of the problem has room to rise. As the main body of learning, students' emotional orientation is directly related to teaching effectiveness. The introduction of situations to meet students' emotional needs can stimulate the internal driving force of students' learning and mobilize their enthusiasm, initiative, and creativity.

(2) Guide Theory (G)

The purpose of designing "Guide Theory" is to train students' autonomous learning ability and solid theoretical knowledge. Vygotsky believes that students' cognitive development is the fastest when the learning tasks are in the most recent developmental area of student learning [41]. This kind of learning task is that students need to complete the task with the help of others. Therefore, according to Vygotsky's recent development zone, in theoretical learning, teachers need to combine the learning content of the project to build a bracket with certain challenges, provide appropriate theoretical knowledge guidance, and arouse the students' recent development zone. Teachers should give proper guidance in this activity and provide timely feedback according to the needs of students. After the students have a preliminary understanding of the learning content, the teacher organizes them to use information technology to collect the expanded knowledge materials related to the project in a group. Then, the group records the collected data and asks the group representative to report the learning results to the class. Finally, the teacher combs and summarizes the knowledge points reported by each group of students to deepen their understanding of theoretical knowledge. In "Guide Theory," students are participatory, and teacher–student interaction should run through the whole link. Group reports are helpful for students to understand the collected knowledge and improve the effectiveness of theoretical knowledge teaching.

(3) Design Plans (D)

"Design Plans" is an essential link for students to apply theory to practice, stimulate students' driving force for innovation, and cultivate their awareness of innovation. Teachers combine the project development process to guide students to design a basic plan, equivalent to the prototype of the project design framework. Based on the students' understanding of the project framework's design, the teacher provides innovative directions and tools to instruct and encourage students to innovate from multiple dimensions such as function, design, and method. Groups apply theoretical knowledge flexibly to implement design and collaborate to propose innovative solutions. "Design Plans" is to integrate the students' "imitation" and "creation" [42], and to change the model of "imitative" learning in the practice of previous students, which will help to cultivate students' diversified creative thinking and STEM literacy.

(4) Comment Plans (C)

Irish writer George Bernard Shaw believes that discussion is a catalyst for ideological innovation [43]. "Comment Plans" is to achieve the purpose of brainstorming and optimizing the plan through the communication between the teacher and the students and between the students. The group representatives will come to the stage to share the creative design concepts, functions, and ideas for the solution. Students think about the feasibility of the scheme and point out the problems and difficulties in the scheme. Finally, the teacher makes comments and suggestions for each group's plan according to the principles of scientificity, feasibility, and practicality, and guides them to optimize the innovative plan. Sharing and discussion can deepen students' ability to find and solve problems, and cultivate their scientific literacy regarding rational innovation. However, to solve the existing problems and difficulties, students need to return to the "Guide Theory" link. The teacher builds a higher level of support to guide the students' theoretical knowledge. The students internalize the relevant knowledge they look up, and then modify the design solution until the problem is solved. In this way, an iterative cycle of "Guide Theory," "Design Plans," and "Comment Plans" is formed, which closely links "Practice in Learning, Innovation in Practice." In learning, students always build new knowledge and improve their ability to analyze and solve problems, integrate subject knowledge, and innovate.

(5) Implement Plans (I)

The implementation of operations is a necessary way to cultivate applied technical talents. "Implement Plans" emphasizes that students should flexibly apply the knowledge they have learned to practical operations. According to the operation manual distributed by the teacher, the students use the existing tools and technologies to transform the group plan into a real product through teamwork. Group cooperation should pay attention to a reasonable division of labor and experience the enterprise team's working mode. In the practice process, the teacher acts as a mentor to conduct patrol guidance, pay attention to the situation of students in practice, develop students' problem-solving ability and cooperation ability in practice, and improve their practical ability.

(6) Display and Evaluate (DE)

The evaluation of learning outcomes consists of self-evaluation, group evaluation, and teacher evaluation. Self-evaluation focuses on finding and filling new knowledge and skills in the learning process; group peer assessments can draw on peers' opinions and suggestions to provide a learning atmosphere for mutual learning and improvement; teacher evaluation focuses on process evaluation rather than just result. By establishing a diversified evaluation path to evaluate students' learning effect, the results of the evaluation will be more comprehensive and objective, which will help the comprehensive development of students' overall quality.

3. Application of the PGDCIDE Model in Maker Course of IoT

3.1. The Design of IoT Maker Course

The IoT will ultimately achieve an intelligent service system that can be widely used in all walks of life to realize the ubiquitous perception, reliable transmission, and intelligent processing of the physical world [44,45]. Therefore, when designing IoT maker courses based on the STEM teaching model, development projects in the fields of agriculture, industry, logistics, transportation, and medical care should be used as much as possible. The close-to-life course project is decomposed into sub-projects for students to ultimately learn to realize the course design of the entire engineering project. Students who are eager to achieve the final result can motivate themself to take the initiative to learn, and have a continuous stream of learning motivation throughout the course. The entire course's learning process is to make use of existing things in order to guide students to give full play to their ideas, hands-on practice to solve problems, and to effectively cultivate their innovative consciousness and practical ability.

In sum, shown in Figure 4 is an example of designing the "Smart Pet Access Control System" project in a smart home to design the maker course. The course needs 32 class hours. The course consists of three parts: the basic explanation of the project, the learning of subprojects, and the comprehensive realization of the project.

(1) The basic explanation of the project needs two class hours and is to introduce the objectives, arrangements, study tips, and basic knowledge of the course;
(2) The "Light up LED" project needs two class hours, and other subprojects need four class hours. The class schedule is allocated according to the difficulty of the subproject. The entire project of the smart pet access control system is divided into seven sub-projects for learning. Each subproject has a corresponding theme and knowledge;
(3) The comprehensive project realization needs four class hours and aims to finally integrate the various sub-projects to complete the intelligent pet access control system.

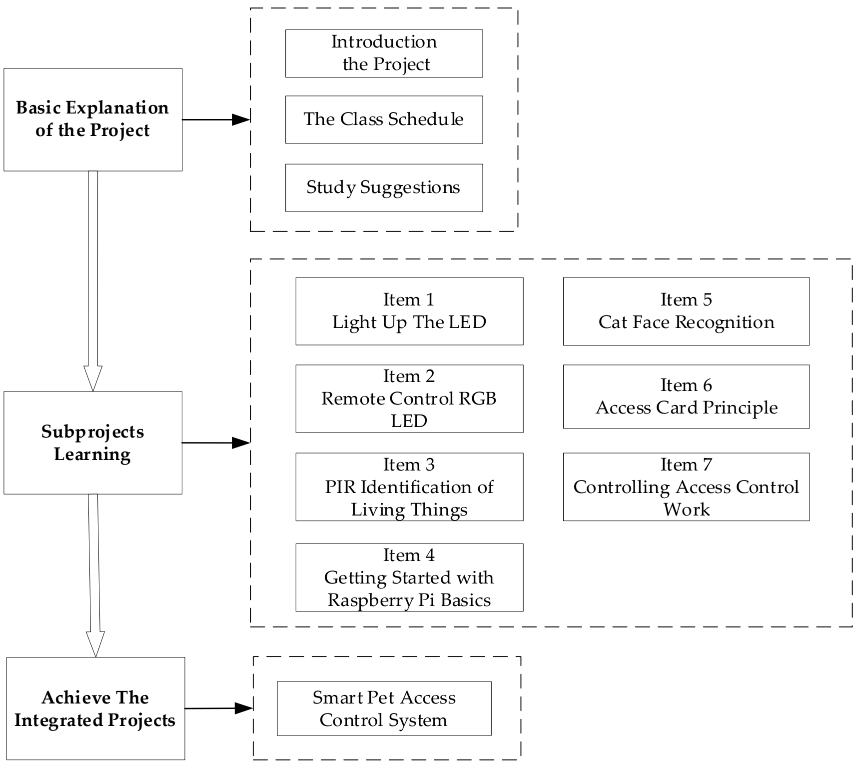

Figure 4. Course design of smart pet access control system project.

The course is suitable for second-year (aged 16 to 17 years) students majoring in the Internet of Things in vocational colleges. Furthermore, it is an elective course that focuses on expanding the subject horizon, deepening the subject knowledge and skills, and cultivating the innovative, practical ability of professionals in the Internet of Things. Students who choose this course to study must have the following prerequisites:

(1) Students should have an interest in learning to implement an intelligent service system because interest is the best teacher;

(2) Possess essential mathematical calculation ability;
(3) Able to read simple circuit diagrams, such as simple circuit symbols;
(4) Have essential computer skills, such as the use of underlying software and information retrieval capabilities.

The primary expected learning outcomes in this course are shown in Table 1. In general, through this course study, students will eventually be able to realize the comprehensive project of intelligent pet access control system, as shown in Figure 5. In terms of skills, students can build circuits, develop simple Android applications, and use open-source hardware. In terms of knowledge goals, students can understand the basic knowledge related to the project, including scientific principles, cutting-edge technologies of the IoT, and the components' working principle. In terms of ability goals, students' integrated knowledge and ability, problem-solving ability, and hands-on practical ability have been improved.

Table 1. The primary expected learning outcomes of the course.

Content	Expected Learning Outcome	Arrangement of the Lessons
Basic Explanation of the Project	Understand the objectives of the course and what is to be learned	2
Item 1. Light Up The LED	Learn to burn the code into Arduino and control the LED light	2
Item 2. Remote Control RGB LED	Create an Android app that requires remote control of RGB LED lights	4
Item 3. PIR Identification of Living Things	Able to use PIR (Passive Infrared Detector) infrared sensors to identify living objects and display the results in the Android App	4
Item 4. Getting Started with Raspberry Pi Basics	① Learn to use the Raspberry Pi's basic operations, run python code, and realize the control of the steering gear ② Turn on the camera via the Raspberry Pi and save the photo to the Raspberry Pi	4
Item 5. Cat Face Recognition	Connect the cat face classifier in open-source computer vision library and run the python code to realize cat face recognition	4
Item 6. Access Card Principle	Realize Arduino to collect RFID (Radio Frequency IDentification) card reader and transmit data to Raspberry Pi	4
Item 7. Controlling Access Control Work	Use the RFID identification card to let the Raspberry Pi control the servo to open the door, and the Android App records the time	4
Smart Pet Access Control System	Integrate the knowledge and skills learned in each project to realize an intelligent pet identification system	4

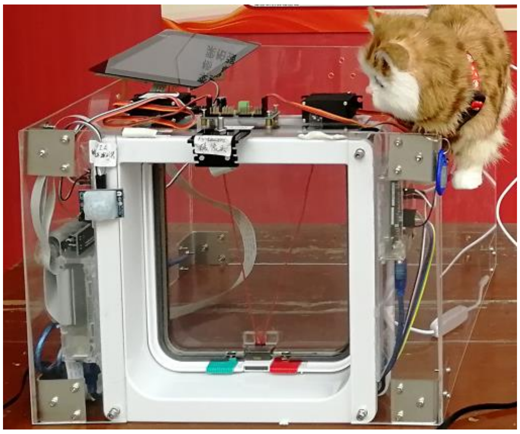

Figure 5. The final renderings of the project.

3.2. The Implementation Case of the PGDCIDE Model

This paper takes the "Remote Control RGB LED" project as an example to introduce the specific implementation of teacher activities (as shown in Figure 6) and student activities (as shown in Figure 7) in each link of the STEM teaching model.

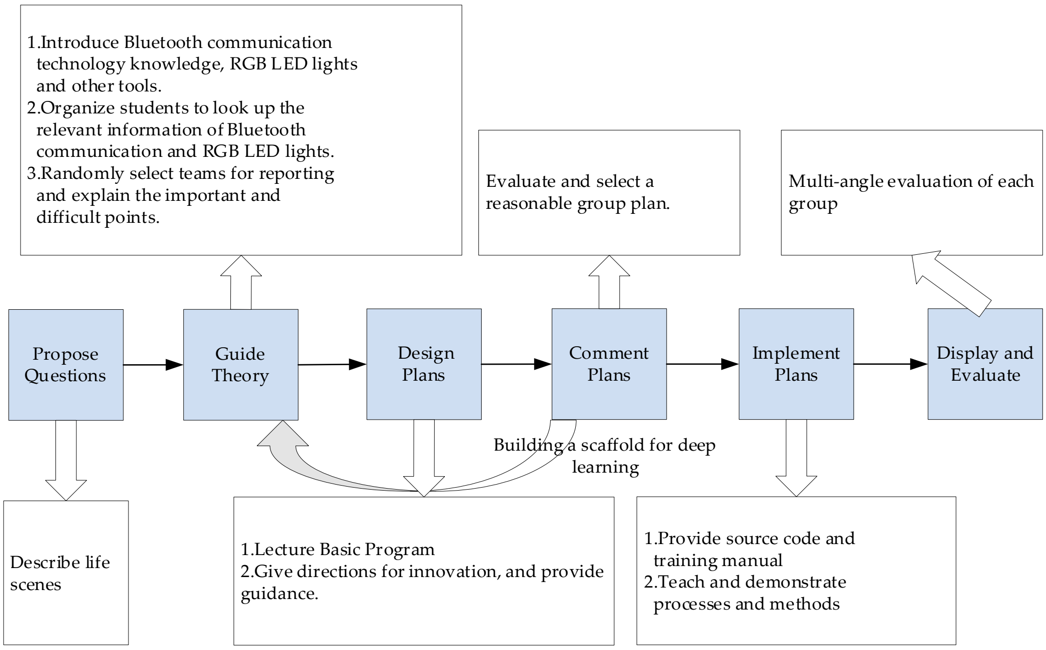

Figure 6. The teacher activities in the PGDCIDE model.

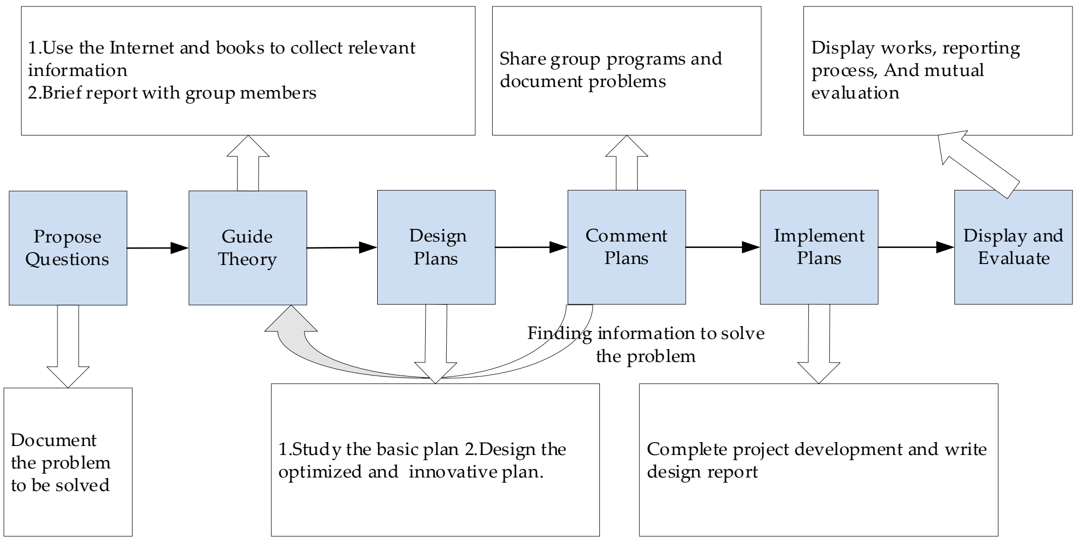

Figure 7. The student activities in the PGDCIDE model.

(1) Create scenarios and propose questions

The teacher can describe such a life situation to propose a problem that needs to be solved:

There is an RGB LED light in Mike's home, which can be switched to different colors. Mike, who had been working for a day, was lying on the bed tiredly. He wanted to change the white light to a dimmer red light, but now he no longer wanted to get up and click the button. The problem we need to solve in this lesson is how to design a system that allows Mike to control the RGB LED light remotely.

Students write down the question raised by the teacher and think about it.

(2) Theoretical guidance and data collection

The teacher introduces the technologies and tools needed to realize the remote control of RGB LED light projects and organizes students to find relevant information on Bluetooth communication technology and RGB LED lights. The searched information includes, but is not limited to, the following:

1) Application field of RGB LED;
2) Primary colors of light and their principles;
3) Pin distribution of RGB LED

After listening to the brief introduction of technology and tools, each group started to surf the Internet or browse books to find relevant knowledge and think about whether an RGB LED can only emit three colors.

During this process, each team needs to record the knowledge found and produce a report. On the other hand, the teacher goes on a tour of inspection, observes students' habits and methods of searching materials, understands students' mastery of knowledge, and guides students to grasp the key points and avoid wrong directions. Finally, the teacher randomly selects three group representatives to report the data they have collected. According to the students' learning situation, the teacher explains the key points and difficult points of the knowledge content and summarizes them.

(3) Brainstorming and design

The teacher first provides a project design flowchart and teaches the basic plan for realizing the project according to the flowchart. Students need to understand how to design the basic plan, and then design the innovative and optimized plan to improve the remote control of RGB LED projects according to different advanced directions. Students discuss in groups of four and try to come up with more innovative solutions and record the ideas of each group on paper. For example, seven RGB LED lights can be combined into a beautiful revolving lantern, which changes the style by the Android application. The voice can be used to control the changes in the RGB LED, and more. In the process of group discussion on the design plan, the teacher goes on a tour of inspection of various groups to give specific guidance to the doubtful groups.

(4) Scheme review and perfect process

The team completed the design and innovation plan and come to the stage to share it. The teacher evaluates the rationality of each group's plan and provides further theoretical guidance to the groups that have difficulties in the plan. The team members then search for solutions in-depth, modify the plan, and solve difficult points. Finally, the teacher provides an Arduino source code related to components and basic program training manual.

(5) Hands-on implementation and cooperative development

The hardware connection diagram is shown in Figure 8. Students work in groups to prioritize projects based on the basic plan, and then optimize projects based on the group's innovative plan. The negative aspects of teamwork experiences are often related to issues of scheduling and unequal contributions between group members [46]. A specific division of labor communication can improve the effectiveness of teamwork and develop students' communication and collaboration skills. Students can form a team of four by themselves, which is conducive to improving team cohesion and achieving complementary teamwork. In an ideal situation, a group of four should have one who takes control of the overall situation while observing design details; one who focuses on hardware design; one who focuses on software design; one who writes a design report. The report template can be referred to in the basic scheme manual, or it can be described in more complete detail.

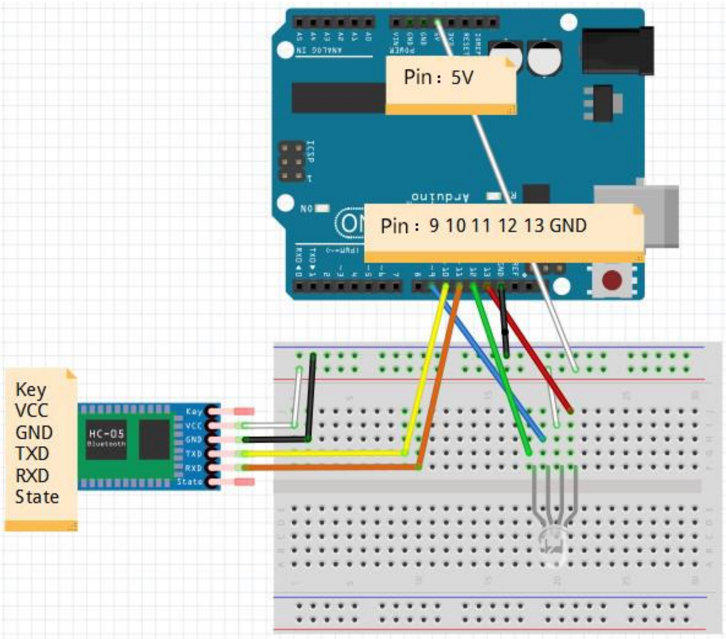

Figure 8. The hardware connection diagram.

The teacher must play the leading role in this link. Not only does the teacher need to pay attention to observe the details of the student designs and understand the students' mastery level of knowledge and technology, but the teacher must also emphasize the division of labor and cooperation between students and try to let the group discuss or consult the material to solve the problem. If the problem cannot be solved, the teacher will give some guidance.

(6) Group presentation and comprehensive evaluation

After completing the project, the teacher chose two groups with better completion levels to present. The presentation mainly included the following:

1) How much has the system design been completed?
2) What is the difference between the group's innovation plan and the basic plan? What are the advantages of the innovation plan?
3) How effective is the system?
4) What exciting things did you learn, and what did you gain?
5) What difficulties did you encounter during the process, and how did you solve them?
6) What are the system shortcomings?
7) Do you have any new ideas about how your system can be improved?

After the group presentation, other groups can comment or ask some questions about the presented group. Finally, the teacher makes a fair evaluation of the whole system design process of the reporting team according to the evaluation criteria shown in Table 2.

Table 2. The evaluation criteria of group design.

Evaluation Index	Evaluation Standard	Weights	Rank					Score
			A	B	C	D	E	
Design	The design is innovative.	15						
	The design is reasonable.	10						
	The design is practical.	10						
Works	The work's completion.	15						
	The work's realization difficulty.	10						
	The work's appearance design.	10						
Team performance	The team's presentation.	10						
	The team's division of responsibilities.	10						
	Teamwork awareness.	10						
Instructions	(1) Adopt the percentage system standard. (2) The grade is A\B\C\D\E five levels, corresponding to excellent, good, general, poor, and poor, respectively, and the coefficient score is 1, 0.8, 0.6, 0.4, 0.2.		The total score					

4. The Application Result Analysis

The IoT maker course based on STEM and open source hardware is a comprehensive practical course aimed at training IoT composite technical talents. The purpose is to allow students to master their professional knowledge and skills while improving their learning interest, ability to analyze and solve problems, hands-on ability, integration of subject knowledge, and innovation ability. Therefore, the following methods are used to analyze the effectiveness of the "Remote Control RGB LED" course.

4.1. Attitude Feedback of the Students

A questionnaire survey was used to obtain feedback on students' attitudes. The questionnaire designed a total of 14 questions to collect students' intentions about the course. Likert-attitude scale questions (1 = strongly disagree, 2 = disagree, 3 = unsure, 4 = agree, and 5 = strongly agree) used in the questionnaire design. A total of 44 questionnaires were distributed, 44 were returned, and 44 were valid. The participants were between the ages of 16 and 17, with 33 boys and 11 girls.

To transform the scaled questions into numerical data, we quantified the Likert-attitude scale responses and conducted a single -sample *t*-test analysis, as shown in Table 3.

The score of course satisfaction ranged from 4.32 to 4.50, with a significant positive difference compared with the test value of three points. This shows that most students believe that the course builds a simple and easy-to-use IoT maker platform, and the learning content can meet their learning needs. The score of knowledge and ability ranged from 4.45 to 4.55, with a significant positive difference compared with the test value of three points. This shows that most students believe that this course's teaching method helps them learn IoT knowledge and technology, and improves their ability to analyze and solve problems, integrate subject knowledge, practice, and innovate. The learning interest score ranged from 4.41 to 4.59, with a significant positive difference compared with the test value of 3 points. This shows that most students are interested in the course's project learning, which effectively stimulates their learning motivation.

Table 3. Single-sample *t*-test analysis of attitude feedback of students.

Dimension	Item	Topic	Mean	S.D.	*t*
Course satisfaction	1-1	The course provides a good maker platform for IoT major.	4.50	0.629	15.82 ***
	1-2	The course's IoT software development platform is easy to get started.	4.32	0.740	11.82 ***
	1-3	The course's IoT software development platform is practical.	4.43	0.661	14.37 ***
	1-4	The IoT software development platform of this course can meet the development needs of Android applications.	4.43	0.661	14.37 ***
	1-5	The program provided by the course is in line with real life.	4.48	0.628	15.59 ***
Knowledge and ability	2-1	The course can help students master IoT knowledge and technology.	4.50	0.591	16.85 ***
	2-2	This course can help students improve their ability to integrate subject knowledge.	4.45	0.663	14.55 ***
	2-3	The course will develop students' hands-on skills.	4.55	0.663	15.46 ***
	2-4	The course allows students to improve their ability to analyze and solve problems.	4.48	0.698	14.03 ***
	2-5	The course can cultivate students' creative ability.	4.52	0.664	15.20 ***
	2-6	The course will train students' engineering thinking.	4.50	0.665	14.97 ***
Learning interest	3-1	Students are interested in the course's IoT hardware platform.	4.41	0.726	12.88 ***
	3-2	Students want to develop mobile terminal applications of the IoT through the IoT software development platform.	4.55	0.663	15.46 ***
	3-3	Students want to be able to take more IoT maker courses based on STEM and open-source hardware.	4.59	0.622	16.97 ***

*** denotes the degree to which the difference is significant.

4.2. The Students' Mastery Degree of IoT Knowledge

To study the students' mastery of the knowledge of IoT after learning through this course, we adopted a single-group experiment method in time series. In the experiment, two quizzes with the same knowledge were prepared. Before the lesson on "Remote Control RGB LED," we conducted a knowledge assessment of students (from now on referred to as "pre-test") and a knowledge assessment of students after class (from now on referred to as "post-test"), to examine students' mastery of basic knowledge of the IoT involved in this course.

A total of 44 test questionnaires were distributed each time, and 44 valid test questionnaires were recovered. The recovery rate of both test questionnaires was 100%.

The pre-test results are shown in Figure 9a, the post-test results are shown in Figure 9b, and the correct growth rate of each question is shown in Figure 10.

In the pre-test, the average score is 46.55, the number of passing students account for only 11.36%, and the student scores are mainly concentrated between 30 and 59. The average score of the post-test is 67.43, and the number of students who pass is 61.36%. In contrast, the students' scores are mainly distributed in the areas of 50 to 59 and 70 to 79. Comparing the results of the pre-test and post-test shows that the average score of the entire students has increased by about 30.97% compared to before class, which effectively improves students' ability to integrate discipline knowledge of IoT.

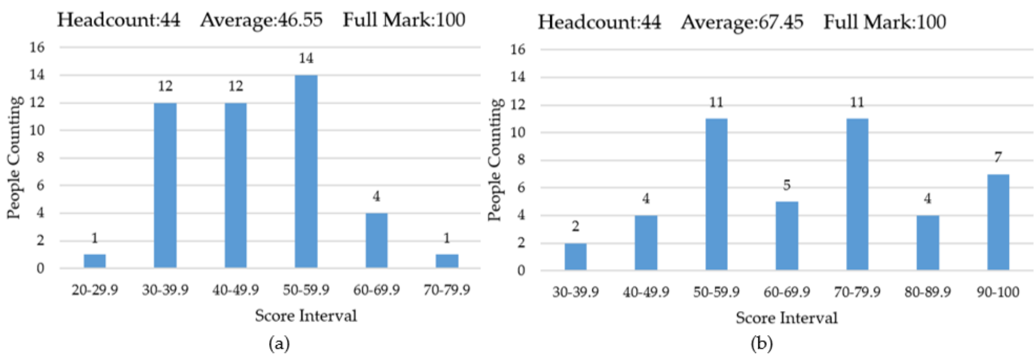

Figure 9. "Remote Control RGB LED" (**a**) pre-test results and (**b**) post-test results.

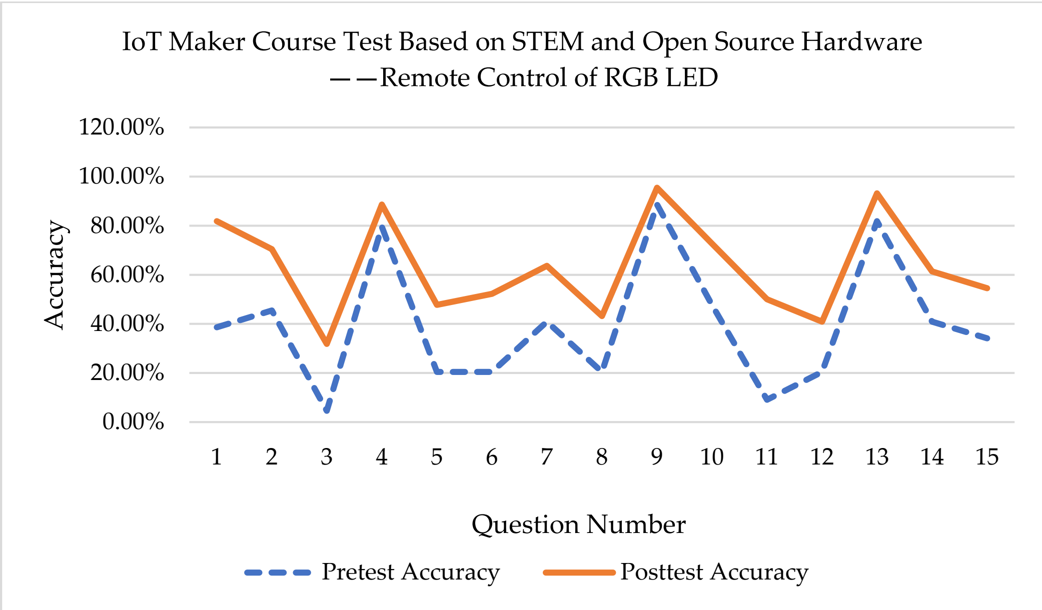

Figure 10. "Remote Control RGB LED" data chart for two tests.

4.3. The Comparison of Two Experiments

In this paper, two groups of experimental methods are adopted, and students who follow the traditional maker teaching method are set as the control group. In the control group, the teacher provided demonstration teaching for students with the operation manual, and the students performed imitation operations. The experimental group uses the PGDCIDE mode for teaching. The experimental group and the control group will verify the effectiveness of the PGDCIDE teaching model by comparing students' attitudes, knowledge of the Internet of Things, and ability performance.

4.3.1. The Students' Attitude Comparison

As shown in Table 4, in terms of course satisfaction and learning interest, the scores of the control group were between 4.02 to 4.27 and 4.14 to 4.36, which was significantly different from the test score of three points. Compared with the experimental group, the difference between the two parts is not large, which shows that the content of the IoT maker course designed in this article is suitable for students of IoT majors in vocational colleges, and students have a high interest in a project-based maker courses. In terms of knowledge and ability, the control group scored between 3.11 and 4.25. Compared with the test score of three, except for the difference in cultivating students' innovation ability, which is not significant, other knowledge and abilities have a significant positive difference. Compared with the experimental group, most students in the control group and the experimental group believe that the maker course will help them learn the knowledge and technology of the IoT, and cultivate practical skills and engineering thinking. However, the experimental group showed distinct advantages in cultivating students' ability to integrate subject knowledge, analysis and problem solving, and innovation. This shows that the maker course can cultivate students' practical ability and engineering thinking in engineering education. Furthermore, the STEM teaching model (PGDCIDE) is more effective in cultivating students' sustainable development ability in engineering education.

Table 4. The analysis and comparison of the single-sample *t*-test of students' attitude feedback.

Dimension	Item		Mean	S.D.	*t*
Course satisfaction	1-1	experimental group	4.50	0.629	15.82 ***
		control group	4.27	0.585	14.43 ***
	1-2	experimental group	4.32	0.740	11.82 ***
		control group	4.02	0.628	10.80 ***
	1-3	experimental group	4.43	0.661	14.37 ***
		control group	4.16	0.608	12.65 ***
	1-4	experimental group	4.43	0.661	14.37 ***
		control group	4.02	0.698	9.71 ***
	1-5	experimental group	4.48	0.628	15.59 ***
		control group	4.14	0.632	11.92 ***
Knowledge and ability	2-1	experimental group	4.50	0.591	16.85 ***
		control group	4.02	0.590	11.49 ***
	2-2	experimental group	4.45	0.663	14.55 ***
		control group	3.41	0.658	4.12 ***
	2-3	experimental group	4.55	0.663	15.46 ***
		control group	4.25	0.615	13.49 ***
	2-4	experimental group	4.48	0.698	14.03 ***
		control group	3.66	0.713	6.13 ***
	2-5	experimental group	4.52	0.664	15.20 ***
		control group	3.11	0.689	1.09 n.s.
	2-6	experimental group	4.50	0.665	14.97 ***
		control group	3.77	0.565	9.07 ***
Learning interest	3-1	experimental group	4.41	0.726	12.88 ***
		control group	4.14	0.594	12.69 ***
	3-2	experimental group	4.55	0.663	15.46 ***
		control group	4.36	0.685	13.20 ***
	3-3	experimental group	4.59	0.622	16.97 ***
		control group	4.25	0.576	14.40 ***

*** denotes the degree to which the difference is significant; n.s. denotes no significant.

4.3.2. The IoT Knowledge Mastery Degree Comparison

The students in the experimental group and the control group were given the same pre-class and post-class knowledge tests. The results of the two experiments were compared to analyze the students' mastery of the Internet of Things knowledge after classroom teaching. As shown in Figure 11a, the comparison of the pre-test results of the two groups shows that the students in the experimental group and the control group have little difference in the overall level of knowledge of the IoT before the class. As shown in Figure 11b, by comparing the post-test results of the two groups, the overall post-test accuracy of the experimental group is higher than that of the control group. Besides, the overall accuracy of the experimental group has increased more than the control group, as shown in Figure 12. This shows that teaching using the PGDCIDE model can more effectively help students learn IoT knowledge.

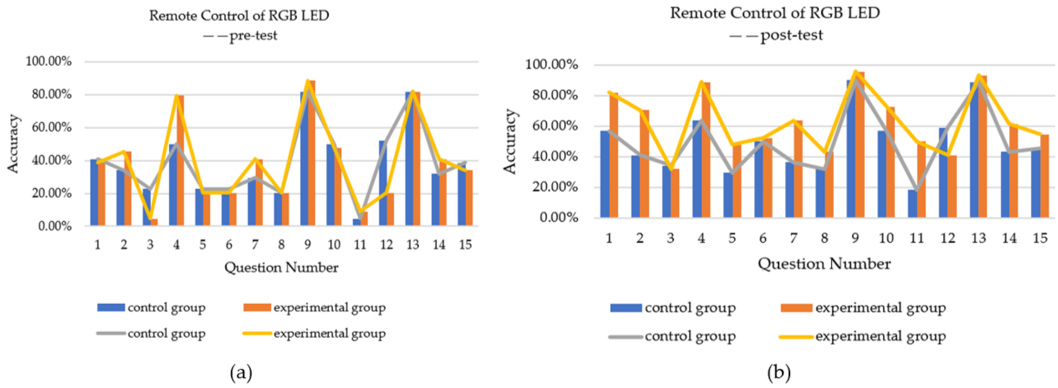

Figure 11. "Remote Control RGB LED" data chart for two tests (**a**) comparison of pretest accuracy between the control group and the experimental group and (**b**) comparison of post-test accuracy between control group and experimental group.

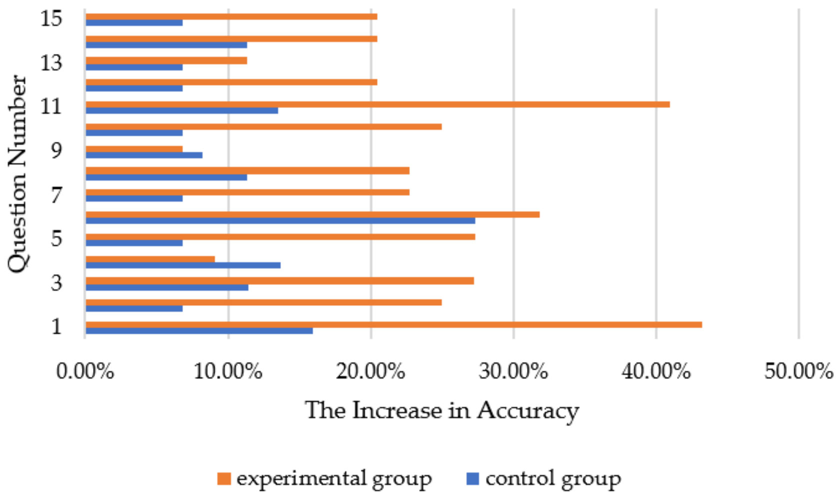

Figure 12. Comparison of the increase in accuracy between the experimental group and the control group.

4.3.3. The Students' Ability in the Performance Comparison

After class, the following questions were asked to the students in the experimental group and the control group:

At present, there are Arduino, several LED lights, human infrared sensor, temperature and humidity sensor, servo motor (steering machine), photosensitive sensor, voice-activated sensor, and ultrasonic sensor. Combined with the Android App, the students were allowed to use their imagination and describe what the students want to achieve works.

The students in the control group proposed to design application software that can remotely control certain types of sensors, such as "I want to be able to control the servo motor through the App." However, the experimental group students could describe the functions of the IoT application in more detail, such as "I hope to be able to control the indoor curtains through the App remotely, and it will use the Arduino and servo motor."

When confronted with problems, the control group students liked to ask questions directly to the teacher. Nevertheless, the experimental group students tended to think for themselves first, communicate with team members, and have a more definite division of labor. They could make full use of resources and quickly collect, sort out, and analyze relevant data. This shows that the students in the experimental group are more outstanding in analyzing and solving problems.

In implementing the plan, the students of the control group only implemented the basic plan. In contrast, the experimental group students added other components such as photosensitive sensors, temperature sensors, and humidity sensors based on the original plan to make the entire system more functional. In contrast, the students in the experimental group had more innovative thinking. The students' performance in the experimental group shows that the PGDCIDE teaching model can effectively train students' innovative ability, ability to analyze and solve problems, and practical skills.

5. Conclusions and Suggestions

By analyzing the current teaching status of Internet of Things maker courses, this paper studies the commonalities between STEM ideas and Internet of Things maker courses as well as different STEM teaching models, and summarizes the core steps of the STEM teaching model: proposing questions, designing plans, implementing plans, displaying and evaluating. Then, we added the steps of theoretical guidance and program reviews on the basis and designed a new STEM teaching model, PGDCIDE. Based on the SWOT analysis of the case results, the following conclusions can be drawn:

(1) Strengths (S). IoT maker courses can attract students' interest in learning. The PGDCIDE model based on the iterative loop for the STEM teaching of the IoT maker course can improve the effectiveness of theoretical teaching and practical teaching, improve students' ability to analyze and solve problems, integrate disciplines knowledge, practice, and innovate;
(2) Weaknesses (W). This research is a preliminary study of the design of the IoT maker course and the teaching model design of PGDCIDE, which uses the purpose sampling and quasi-experimental research methods. Therefore, the research has certain limitations. From the analysis of the implementation process and learning effect of the PGDCIDE model in the IoT maker course, some aspects are worth further exploration and correction;
(3) Opportunities (O). The PGDCIDE teaching model has joined the theoretical guidance link. From the perspective of the changes in students' knowledge mastery, the teaching model is beneficial to solve the problem of the lack of theoretical learning in the maker course. The PGDCIDE model also focuses on cultivating students' independent design rather than imitating operations, which has reference significance for maker courses' teaching design;
(4) Threats (T). The students aged between 16 and 17 years old in the IoT major at the vocational college were expected to concentrate on learning to complete the intelligent pet access control system. Therefore, they were able to only show they can only to show a simple prototype, not a product that can be used in life. In future research, we can probe into the specific evaluation of the PGDCIDE teaching model on the IoT maker course and related teaching experiments.

Finally, this paper analyzes the STEM teaching model's implementation effect based on the students' learning feedback. It puts forward the following three suggestions for designing the maker course of the Internet of Things major:

(1) In the IoT maker course, this paper decomposes the "Smart Pet Access Control System" project in smart home design into sub-projects for students to learn. Based on student feedback, they are happy to learn life-related course items. Therefore, designing the IoT maker course's project should focus on attracting students' interest to stimulate their internal motivation to learn;
(2) In the teaching design of maker courses, this paper focuses on the guiding role of teachers and the cooperation and exchange between students. The result shows that, with teacher guidance, the teaching effect of students' self-directed learning is better than traditional imitation teaching. Therefore, in the teaching of the IoT maker course, we should pay attention to the interaction design between teachers and students and students in order to improve the participation of students in learning;
(3) This paper combines "theory, practice, and innovation" in the teaching of maker courses. Students learn theoretical knowledge, then give full play to their ideas, and apply the learned theoretical knowledge to the practice of solving problems. The experimental results show that this can improve the effectiveness of theoretical knowledge teaching and cultivate students' innovative

awareness and practical ability. Therefore, in the teaching of IoT maker courses, emphasizing students' practice in learning and innovation in practice can improve the teaching value of maker courses.

In response to the implementation of the Internet of Things strategy, schools need to pay more attention to the development and implementation of maker courses to enhance the overall quality of applied technology talents in the new era and deliver high-quality talent resources for enterprises.

Author Contributions: Conceptualization, R.C., J.R. and H.Z.; Methodology, J.R. and H.-Z.T.; Validation, X.X.; Writing—original draft, Y.Z.; Writing—review & editing, R.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Innovation Team Project (Natural Science) of the Education Department of Guangdong Province (No.2017KCXTD021), the Engineering Construction Project of Teaching Quality of Guangdong Province–the characteristic specialty: Internet of Things Engineering (2018), the Construction Project of Quality Engineering of Guangdong Polytechnic Normal University (No.2017ZYZG05), the Research and Practice Project of Education and Teaching Reform in Higher Vocation of Guangdong Province (No.GDJG2019082), the Educational Science Project Foundation of Guangdong Province (No.2013JK341), the Project for Distinctive Innovation of Ordinary Universities of Guangdong Province (No.2018KTSCX120), the Ph.D. Start-up Fund of Natural Science Foundation of Guangdong Province (No.2016A030310335), the National Natural Science Foundation of China(No.61672008), the Graduate Education Innovation Project of Guangdong Province (No.2020JGXM079), Guangdong Colleges and Universities Young Innovative Talents Projects (2018KQNCX138).

Acknowledgments: The authors would like to appreciate the contributions from Digital Content Processing and Security Technology of Guangzhou Key Laboratory of School of Computer Science, Guangdong Polytechnic Normal University.

Conflicts of Interest: The authors declare no conflict of interest.

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