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Teaching Reform in C Programming Course from the Perspective of Sustainable Development: Construction and 9-Year Practice of "Three Classrooms–Four Integrations–Five Combinations" Teaching Model

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Abstract: In the past, the teaching of C programming courses was teacher-centered, and students' practical ability, innovation ability, independent learning ability, and moral character were not effectively improved. In order to meet the requirements of teaching informatization, OBE philosophy, "Golden Course" construction, and ideological politics in the curriculum for course teaching, we have been reforming how C programming courses are taught since 2013 from the perspective of sustainable development in order to realize the synergistic promotion of knowledge imparting, ability training, and moral character shaping. First, we systematically reformed the teaching support system in eight dimensions: changing the teaching philosophy, enriching teaching resources, reconstructing the teaching environment, reshaping the course content, transforming the teaching process, innovating teaching methods, reforming course evaluations, and building ideological politics surrounding the ecology of the curriculum. On this basis, we divided the teaching classroom into three classrooms: theory, practical training, and innovative practice. We ensured that teaching resources, information technology, diversified evaluation, and moral character shaping were always integrated into the classroom. Then, we used a combination of "online and offline, in-class knowledge learning and extra-curricular autonomous practice, teachers' careful lectures and seniors' guidance, ability training and moral character shaping, and impart knowledge and innovative practice" to build a student-centered teaching model of "three classrooms–four integrations–five combinations". Since the application of this model in course teaching, students have not only enhanced their sense of access to learning and improved their course performance, independent learning ability, and practical ability, but have also improved their innovation ability, with students achieving excellent results in thesis publication, patent applications, software copyright applications, discipline competitions, and innovation project applications. Students have cultivated a strong sense of social responsibility and high moral character, and employers are highly satisfied. This teaching model has been adopted and reused in 12 engineering courses and has achieved good application results. The teaching model can provide a reference for college engineering courses to build a student-centered information-based education ecology, create high-quality classrooms, and collaboratively improve students' abilities and moral character.

Keywords: teaching mode; sustainable development; training abilities; shaping the moral character

Citation: Yao, D.; Zhang, X.; Liu, Y. Teaching Reform in C Programming Course from the Perspective of Sustainable Development: Construction and 9-Year Practice of "Three Classrooms–Four Integrations–Five Combinations" Teaching Model. *Sustainability* **2022**, *14*, 15226. https://doi.org/10.3390/su142215226

Academic Editor: Michail Kalogiannakis

Received: 30 October 2022
Accepted: 15 November 2022
Published: 16 November 2022

1. Introduction

C programming is a very practical course for computer majors and is one of the basic core courses. Students need to master programming knowledge through a great deal of programming training and practice, improve their programming ability, and gradually understand and master the ideas and methods of programming. Teachers must create an environment that is conducive to cultivating students' practical ability when teaching the

course to improve students' practical ability in programming. With the gradual implementation of the Engineering Education Professional Accreditation [1] for computer majors in China, the Ministry of Education of China proposed strengthening the construction of the "Golden Course" in the new era, implemented the "Double Ten-Thousand Plan," [2] and fully implemented the requirement of the ideological politics in the curriculum [3]. Thus, C programming course-teaching reform should not only focus on cultivating students' practical ability but should also meet the OBE requirements of professional engineering certifications while also continuing to build students' moral character through teaching the course and comprehensively implementing quality education. Therefore, many scholars have carried out corresponding teaching reforms on C programming courses according to the emerging new requirements, which can be divided into the four aspects discussed in the sections below.

1.1. Teaching Reform of Course Informatization

Educational information allows teachers to build an environment for improving the practical ability of C programming courses. The concept of educational informatization [4] was put forward in the 1990s with the construction of the information superhighway. The core content of educational informatization is teaching informatization. Teaching informatization means making teaching scientific and technological information, education on the dissemination of informatization, and the teaching of method modernization. In April 2018, the Ministry of Education of China issued the "Education Informatization 2.0 Action Plan" [5], which requires the comprehensive use of modern information technology based on computer, multimedia, big data, artificial intelligence, and network communication in education to promote educational reform and to meet the new requirements of the modern-day information society in education. It is of great significance to deepen educational reform and implement quality-oriented education. Under the requirements of educational informatization, many teachers have carried out many teaching reforms on C programming courses. For example, Fu et al. [6] and Zheng et al. [7] improved course practice teaching by using teaching software and autonomous learning platforms, realized the sharing of teaching resources, improved students' interest in learning, and enhanced students' programming ability. However, this course teaching reform mainly provided information-teaching resources, changed the teaching process, cultivated interest in learning, and did not truly implement the "student-centered" teaching concept or promote the innovation of teaching methods.

1.2. Teaching Reform Based on OBE

The Engineering Education Professional Accreditation is an international quality assurance system for engineering education and an important basis for international mutual recognition of engineering education and engineering qualifications. Outcomes-Based Education (OBE) was proposed by William G. Spady in 1981 [8]. In contrast to traditional educational concepts, OBE is neither teacher-centered nor knowledge-content driven but is instead student-centered and focused on student learning outcomes. China was accepted as a signatory to the Washington Agreement in June 2013. Against the background of the Engineering Education Professional Accreditation, because of the gap in how C programming courses are taught, in line with the outcomes-oriented principle, many scholars put forward that C language courses should undergo teaching reform based on the concept of OBE. For example, Cai [9] proposed reforming C programming course teaching based on the OBE concept to optimize C programming course teaching and to improve teaching quality. Fan et al. [10] explored the application of the OBE concept in the teaching reform of C programming courses, taking a project-driven teaching method and multi-dimensional teaching mode to cultivate students' practical ability to promote the cultivation of thinking and innovation ability as well as engineering practice ability in new engineering students. Liu et al. [11] formulated teaching objectives for C programming courses based on the OBE concept, optimized the teaching content, adopted a mixed offline

and online teaching model, and constructed a sustainable and improved assessment and evaluation system. Based on the idea of engineering education, Li et al. [12] established a new engineering-oriented curriculum system by designing innovative teaching models, advanced teaching methods, and optimized teaching objectives to cultivate interdisciplinary talents with strong engineering practice ability. Zhang et al. [13] proposed designing a hybrid teaching model supported by multiple teaching platforms and conducted cluster analysis on learning data generated by online learning activities, thus providing a direction for the continuous improvement of teaching. These studies provide a good reference for adapting C programming course teaching reform to the requirements of OBE and promoting the transformation of traditional education concepts. However, innovation in teaching resources and in the teaching environment should be strengthened to promote the collaborative improvement of knowledge, ability, and quality.

1.3. Teaching Reform Based on the Requirements of the "Golden Course"

In 2019, the Ministry of Education of China proposed the requirement of strengthening the construction of the "Golden Course" in the new era and implemented the "Double Ten-Thousand Plan" for national and provincial first-class courses [2]. It is clearly required that course teaching undergo changes in teaching concepts, explore new connotations in the teaching paradigm, take students as the center focus, carry out resource construction and environment construction, and integrate online and offline learning in-class and after-class as well as before and after class as a whole. It proposed that curriculum construction should have "High-order, Innovation, and Challenge". As a result, many teachers have implemented teaching reform in C programming courses and have designed a number of blended C programming teaching models based on online and offline learning. For example, the research results of Demaidi et al. [14] showed that compared with traditional learning, blended learning significantly improved students' academic performance, and students were satisfied with the convenience of using blended learning methods and the degree of suitability for programming and submitting homework. Alammary [15] showed that blended learning is more effective than traditional teaching and can improve students' learning experience. Zhao [16] presented an implementation process of hybrid teaching methods based on an analysis of micro-classroom, flipped classrooms, MOOCs, and other teaching methods. Hybrid teaching methods have greatly helped students to improve their self-study ability, practical ability, learning interest, enthusiasm, and initiative. Ma et al. [17] used a combination of the C programming course and network tool software to build a new hybrid teaching model that effectively made up for the defects of a single online platform and effectively improved the quality of online teaching. Li et al. [18] proposed adopting the SPOC hybrid teaching model. By clarifying the roles of teachers and students, developing an interactive teaching model, using case teaching, enriching SPOC resources, and providing timely feedback, students' reading and writing abilities and computational thinking improved. Wang et al. [19] combined the advantages of online and offline teaching to create a hybrid "golden course" teaching model that promotes strengths and avoids weaknesses, makes online and offline learning complement each other and improves teaching quality. Yuan [20] guided students' interest in learning and emphasized students' learning processes by constructing a mixed teaching model on the MosoTeach platform. The course teaching reforms mentioned above have strengthened the combination of online and offline as well as in-class and extra-curricular learning, have broken the time and place restrictions of traditional offline teaching, have realized the sharing of high-quality teaching resources and learning feedback, have provided a learning environment for students to learn the course content comprehensively, and have strengthened students' autonomous learning ability. However, these teaching reforms do not reflect how to support the corresponding graduation requirements for the engineering education certification, do not implement ideological politics in the curriculum to achieve value guidance, and do not fully reflect the concept of continuous improvement.

1.4. Teaching Reform Based on Curriculum Ideology and Politics

In June 2020, the Ministry of Education issued the Guideline for the Construction of Curriculum Ideological and Politics in Higher Education. It is required that fostering virtue through education be carried out throughout the whole teaching process and all aspects of classroom teaching to help students establish correct value judgment and value choices [21]. Once again, the program puts forward new requirements for course teaching. As a result, many teachers of C programming courses studied the related research results on how to effectively implement education, such as those provided by Li et al. [22], in the process of teaching moral education to integrate socialist core values and to reform teaching content and methods. Shi [23] integrated ideological and political elements into the C programming course in various ways to cultivate excellent successors with national feelings and knowledge, ability, and quality in line with the requirements of the new era. These studies effectively integrated curriculum ideological politics into teaching, strengthened teachers' value guidance and personality shaping for students in their teaching, and promoted the combination of ideological politics and ability training into the curriculum. However, it ignores the comprehensiveness and integrity of course reform. It only focuses on strengthening the ideological politics of the course curriculum without considering the effective combination of reforming the educational environment, teaching methods, and curriculum evaluation.

However, there are two deficiencies in the above four aspects of teaching reform. First, all teaching reforms are conducted from the standpoint of the scholars' own research, which has obvious limitations. There is a lack of research results on innovation reform in teaching from the perspective of systematic and sustainable development. Second, in the era of the comprehensive implementation of quality-oriented education, curriculum teaching reform fails to effectively realize the synergistic promotion of knowledge imparting, ability training, and moral character shaping.

Therefore, we propose a new teaching reform for C programming courses. Based on the perspective of sustainable development, a holistic and collaborative reform is carried out in eight areas: changing the teaching philosophy, enriching teaching resources, reconstructing the teaching environment, reshaping the course content, transforming the teaching process, innovating teaching methods, reforming course evaluations, and building an ecology of ideological politics into the curriculum. A new ecology of "student-centered" education based on information-based teaching resources has been created, forming a new teaching model known as "three classrooms–four integrations–five combinations" and "four-in-one" strategies that promote the imparting of knowledge, the training of abilities, and the shaping of moral character. This model not only meets the needs of "Golden Course" construction in the new era but also effectively supports the professional certification of engineering education and still focuses more on integrating ideological and political elements. It effectively stimulates student initiative in learning during the course; promotes moral character shaping, ability training, and knowledge imparting; enhances students' sense of access to learning; improves their practical and innovative abilities; and shapes their quality of character. It can provide a reference for university courses to build a student-centered information-based education environment, create quality classrooms, and collaboratively enhance students' abilities and moral character.

2. Basic Information about the C Programming Course

2.1. Main Content

Huaihua University is a local undergraduate institution that aims to cultivate application-oriented talents and to adhere to the orientation of "building application-oriented disciplines, running application-oriented majors, doing application-oriented research, cultivating application-oriented talents, and building an application-oriented university". The School of Computer Science and Artificial Intelligence of Huaihua University has five majors: Computer Science and Technology, Network Engineering, Software Engineering, Data Science and Big Data Technology, and Artificial Intelligence. Each major adheres to

OBE (outcome-based education) engineering education and focuses on cultivating students' practical engineering abilities. The objective of each major is to cultivate application-oriented talents that are competent in complex engineering and technology problems in the corresponding industry fields of each major.

According to our school's orientation and professional training objectives, the C programming course is a core foundation course for all majors in the school, comprising 80 credit hours and four credits. The course needs to train students with programming abilities that can be applied to effectively solve real-world problems, effectively supporting the three graduation requirements of engineering knowledge, research, and communication outlined in the Engineering Education Professional Accreditation [24]. The course initially consists of 15 knowledge modules, including Programming and C Language; Algorithms; Sequential Programming; Selection Programming; Loop Programming; Nested Loops; Arrays; Character Arrays; Functions; Local Variables and Global Variables; Pointer Variables; Relation of Pointer to Array and Function; Dynamic Memory Allocation; Structs; and Unions.

2.2. Main Objectives

According to our university's orientation "to build a regional high-level application university", we take the teaching philosophy of cultivating ability, improving quality, and shaping character and constantly strive to enhance the curriculum's advanced, innovative, and challenging nature. The curriculum is designed to effectively support the three graduation requirements of engineering knowledge, research, and communication in the professional engineering education certification for computer science majors and to cultivate students with craftsmanship ability. We have identified this course's knowledge, competency, and quality objectives as follows:

(1) To enable students to master the basic syntax of the C language, the basic flow of programming, the basic ideas of typical algorithms, the basic structure of programs, and the basic methods of program debugging, which are five types of basic knowledge, and to have a good programming style.
(2) Faced with complex engineering problems [25] in computing, students can select appropriate data structures to determine algorithms, implement them using C, and develop logical thinking, analytical problem-solving skills, and programming practice abilities.
(3) To equip students with the four qualities of reading and writing programs, team spirit, innovative applications, and lifelong learning.

2.3. The Urgency of Course Teaching Reform

For a long time, teachers have been regarded as the main body for teaching the truth, teaching skills, and answering questions. The educational concept of "teacher-centered" has been deeply rooted in people's hearts. In this mode of teaching and learning, C programming courses mostly adopt traditional teaching methods, and students combine the practical operation of the computer to consolidate and familiarize themselves with the knowledge points learned in the classroom. Although this conventional teaching mode can train students to have a good theoretical basis and a certain practical ability, their abilities to conduct a specific analysis of problems and their problem-solving ability are poor, and there is a general lack of comprehensive application of knowledge to solve practical problems, and students lack moral shaping. It is not easy to cultivate talent with social responsibility and an ability to meet social needs.

The rapid development of today's society requires students to have the ability to learn independently, innovate and practice, and have good moral character and social responsibility. To cultivate these abilities as well as the moral character of students, teachers can no longer continue the previous methods of indoctrination teaching and need to implement the "student-centered" teaching philosophy, emphasizing the student-centered and focusing on guiding and inspiring students so that they can have independent learning ability innovation ability as well as the ability to solve complex engineering problems.

The continuous shaping of students' morality in teaching gives them a strong sense of social responsibility. Therefore, it is urgent to carry out teaching reform in C programming courses; realize the organic integration of knowledge imparting, ability training, and moral character shaping; and cultivate the talent that society really needs.

3. Analysis of Teaching Pain Points and Countermeasures

3.1. Teaching Pain Points

(1) Teaching philosophy: The C programming course has many knowledge points, and teaching modes using traditional teaching philosophies are not sufficiently personalized or innovative to support the cultivation of students' ability to solve complex engineering problems. There is no overall conception of course construction, and course teaching is still teacher-centered.

(2) Independent learning: Students are mostly passive learners and lack effective teaching resources to support independent learning. There is also a lack of effective online platforms to facilitate knowledge review, practice, training, and consolidation.

(3) Teaching methods: It is common to see "spoon-fed" information and silence in the classroom without the use of appropriate methods to enhance students' computational thinking abilities, programming practice, and innovation.

(4) Course evaluation: Course evaluation only uses examination results and usual grades to measure performance. Moreover, examinations are mostly written by the lecturers who taught the course without implementing the separation of teaching and examination, which lacks comparability and cannot effectively assess students' knowledge mastery and programming practice ability.

(5) Ideological politics in the curriculum: Ideological politics in the curriculum means that the ideological and political elements of education, including theoretical knowledge, values, and the spiritual pursuit of ideological and political education, are integrated into the curriculum to influence students' ideologies and behavior in a subtle way. There is currently a lack of course application cases and the design of an organic combination of political elements. Achieving the implementation of ideological politics into the curriculum and the implementation of the goal of moral education are very difficult.

3.2. Countermeasure Analysis

To address the above teaching pain points, we must focus on how to achieve the objectives of the C programming course, pay attention to the overall design of teaching reform, and systematically reconstruct the teaching of the course from eight dimensions: changing the teaching philosophy, enriching teaching resources, reconstructing the teaching environment, reshaping course content, transforming the teaching process, innovating teaching methods, reforming course evaluations, and building an ecology of curriculum ideological politics, as shown in Figure 1. A student-centered, value-led, competence-first, more open, and personalized course-teaching support system was constructed. It will break through the previous phenomenon of emphasizing knowledge over morality and exam results over ability and realize the collaborative promotion of imparting knowledge, training ability, shaping moral character, and cultivating application-oriented talent with practical ability, innovation, and social responsibility.

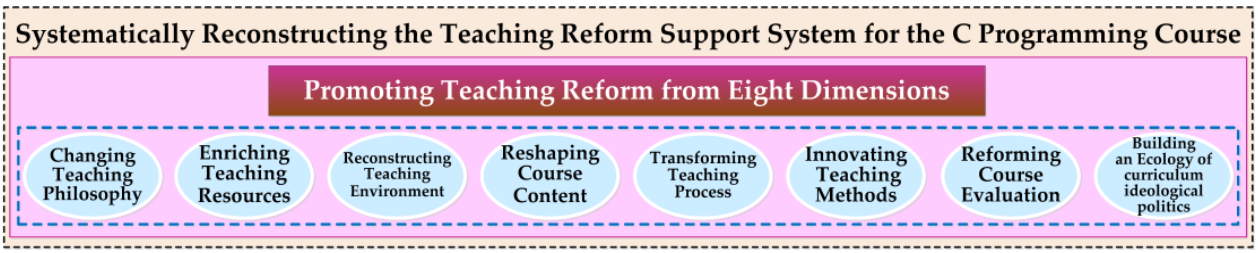


Figure 1. Teaching reform support system.

4. Design of Teaching Reform and Construction of the Teaching Model

4.1. Design of Teaching Reform

(1) Change the teaching philosophy to form a conceptual shift conducive to ability training and moral character shaping.

Teaching philosophy is the basic attitudes and concepts people hold about teaching activities and the belief that people engage in teaching activities [26]. There are theoretical, operational, and disciplinary levels of teaching philosophy. A clearly expressed teaching philosophy is important in guiding teaching activities [27].

By organizing many major discussions on teaching philosophy among the teaching team, we have broken through the confines of the traditional teaching model and have established a new teaching philosophy that develops students' abilities and shapes their moral character as the core of the course. We have made five changes: teaching methods have changed from teaching-oriented to learning-oriented; teaching resources have changed from serving to teach to serving to learn; the teaching space has changed from classroom-based to a combination of online and offline learning; teaching content has changed from imparting knowledge to ability training and moral character shaping; teaching evaluation has changed from results-based to process-based.

(2) Enrich teaching resources and provide quality resources conducive to open sharing in course teaching.

Teaching resources are the core of the construction of the course network's learning system and can be used for network course construction, learning resource sharing, and various teaching services such as network teaching services and autonomous learning services [28].

We gathered high-quality resources through self-construction, introduction, and sharing and improved the scale and quality of resources. These include MOOC/SPOC teaching platforms, micro-courses on important and difficult knowledge, the ACM online judging system, the basic theory of the teaching system, the Educoder practical training teaching platform, the Huaihua University online examination system, and the joint examination platform (PTA). The diversified network of teaching resources (as shown in Figure 2) was constructed to activate practical activities inside and outside the classroom, realize the open sharing of the course inside and outside the school, and guarantee the smooth implementation of practical and innovation ability training.

(3) Reconstructing the teaching environment and forming a teaching ecology conducive to collaborative integration inside and outside the classroom.

Educational ecology was first proposed in 1976 by Cremin, former dean of the Teachers College of Columbia University, to study the problems in education and teaching using the theories and methods of ecology [29]. With the advent of information technology in education, it has gradually evolved into an analysis of the current situation of education and its problems in the information technology environment from an ecological–philosophical perspective. It involves studying the relationship between various ecological factors in the teaching environment and education in order to promote the harmonious, balanced, and sustainable development of "people and people, people and the environment" in the education process and to promote the sustainable development and virtuous cycle of teaching reform [30]. Constructing a teaching classroom ecology involves implementing the teaching concepts of equality and sustainability for all as advocated by education ecology. It is a student-centered classroom that emphasizes each student's needs, desires, and consciousness; considers the development of students' personalities; and realizes the true unity of teaching and student development through modern classroom teaching methods.

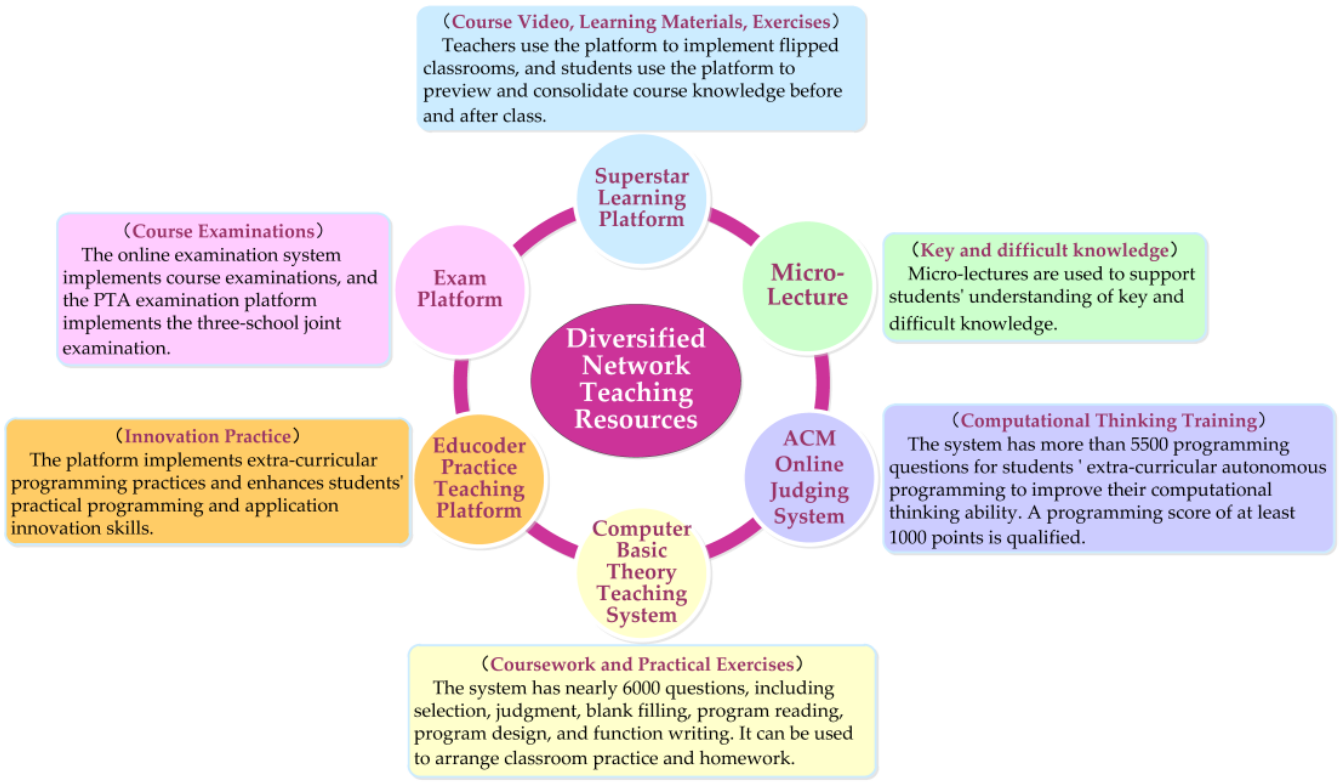


Figure 2. The diversified network of teaching resources.

Through constructing an information-based teaching environment, we have synergistically integrated online and offline, inside and outside, and before and after classes, realizing functions such as rich media content presentation, interactive questions and answers, contextual perceptions, teaching assessments, online examinations, and independent learning. It creates a new teaching ecology that is truly student-centered, reflects individual needs, stimulates students' interest and initiative in learning, and implicitly stimulates students' innovative spirit and critical thinking.

(4) Reshaping the course content to form ability modules conducive to the progressive implementation of project-based teaching.

OBE emphasizes competency-based as well as outcome-based education measures to determine what students can do, not what students know, which is something that traditional education cannot do. For example, a common method used in traditional education to measure what students know is to choose a correct answer from several given answers. This method usually tests the student's memory, not what they have learned. OBE requires students to expand on the way that they mastered the content: from the ability to solve problems with fixed answers to the ability to solve open-ended problems [31]. OBE requires students to demonstrate their abilities through challenging tasks such as making project proposals, completing project planning, conducting case studies, and giving oral presentations. Such tasks allow students to demonstrate their ability to think, question, research, decide, and present. Therefore, OBE places students in an environment that develops their design abilities to complete a process. OBE focuses more on higher-order competencies, such as thinking creatively, analyzing and synthesizing information, and planning and organizing. This ability can be gained by working in teams by completing more complex tasks.

Based on the above point of view, we have reshaped the course content according to ability modules, from the original 15 knowledge modules to 10 ability modules. We changed the emphasis from theoretical to practical teaching, from knowledge imparting to ability training and moral character shaping, as shown in Figure 3. We have added high

order and innovation to the teaching content to guarantee the systematicity and challenge of knowledge. This makes it possible to meet the needs of engineering education professional accreditations, regional economic development, industrial transformation and upgrading, and the need to implement project-based teaching in the course. It can effectively drive students to take initiative and improve their interest in learning and in learning efficiency. In addition, teachers combine mainstream values and naturally infuse feelings of home and country into all aspects of the course, penetrating them by degrees to reach their hearts.

No.	Knowledge modules	Lecture	Practice
1	Programming and C Language	2	0
2	Algorithm-the Soul of the Program	2	0
3	Simplest C Programming - Sequential Programming	4	2
4	Selection Programming	6	2
5	for Loop Programming	4	2
6	while and do while Loops	4	2
7	Nested Loops	2	2
8	One-dimensional Array	2	2
9	Two-dimensional Array	2	2
10	Character Array	2	2
11	Functions and Arguments to Functions	4	2
12	Local Variable and Global Variable	2	2
13	Pointer variables	4	4
14	Relation of Pointer to Array and Function	4	2
15	Dynamic Memory Allocation	2	2
16	Structs and Unions	4	2
		50	30

Restructuring Knowledge Modules into Ability Modules

From Knowledge Imparting to Abilities Training and Moral Character Shaping

No.	Ability module	Allocation of teaching hours by session		
		Lecture	Practice	Total
1	C Program Editing and Running Ability	2	2	4
2	Algorithm Design Ability	2	2	4
3	Data Expression Design Ability	2	2	4
4	Sequential Programming Ability	2	4	6
5	Select Programming Ability	2	4	8
6	Loop Control Design Ability	4	6	10
7	Array Problem Solving Ability	4	4	8
8	Function Problem Solving Ability	6	6	12
9	Problem Solving Ability Using Pointers	4	10	14
10	Problem Solving Ability Using Structs and Unions	6	8	14
		32	48	80

Figure 3. Restructuring of course content by ability modules.

(5) Transforming the teaching process and developing collaborative teaching strategies to facilitate the implementation of the teaching model.

A teaching strategy [32] is the plan for the teaching process and the measures are taken to implement teaching and learning in a given teaching situation to achieve the teaching objectives and to meet the student's cognitive needs. It includes the reasonable organization of the teaching process, selecting specific teaching methods and materials, and formulating the teaching behavior procedures followed by teachers and students. In order to effectively implement the teaching model, the four-in-one teaching strategy of "understanding during learning, strengthening during exercises, consolidating during practice, and innovating during breakthrough" is adopted. We carefully designed PPT presentations and C programs in the lecture courses and adopted teaching methods such as heuristics, comparison, lecture and practice, question and answer, and discussion to achieve "understanding during learning". We carefully designed the post-course assignments and allowed students to complete them through the online platform to achieve "strengthening during exercises". In the practical training courses, we use demonstration, practical operation, real-time tutorials, and systematic evaluation to achieve "consolidation during training". During extra-curricular practical training, we set breakthrough program problems on the Educoder practical training platform. By independently completing the practical training on the platform, students further improve their independent learning, analysis, problem-solving, and innovation ability, thus realizing "innovation during breakthrough". This will help to implement the teaching model and to overcome the problem of insufficient collaboration and incoherence in classes, thus creating a new form of classroom teaching.

(6) Innovative teaching methods to achieve a seamless transition conducive to the collaborative promotion of ability training and moral character shaping.

Teaching methods are learning methods that are guided by certain teaching philosophies and principles to achieve the teaching objectives and to complete teaching tasks [33]. It includes the methods taught by teachers and the learning methods of students under the guidance of teachers. It includes a high degree of integration and organic unity between the methods taught by teachers and the methods learned by students in teaching activities.

In the design of the teaching methodology for the C programming course, students learn the course knowledge and enhance their self-learning ability through online learning, exercises, and discussions before class. In-class, teachers impart knowledge through problem-based, project-based, and seminar-based approaches to enhance students' sense of access and participation in class. After class, students extend their learning through practice assignments and innovative training projects to enhance their generic learning ability. During practical training, students improve their ability to solve complex problems through hands-on programming, group discussions, presentations, mutual teaching, and learning combined with teacher evaluations of comprehensive problems and more formal explanations. Exams are used to check the effectiveness of students' learning. Teachers use the feedback from the exam results to determine whether students can learn subsequent course content and can also be used as a reliable basis for teachers to revise the course teaching schedule and teaching methods. The whole process implicitly incorporates elements of ideological politics in the curriculum to achieve moral character shaping. The teaching methods are always student-centered, achieving a seamless integration of all teaching aspects of the course and synergistically promoting the development of students' abilities and moral character shaping, as shown in Figure 4.

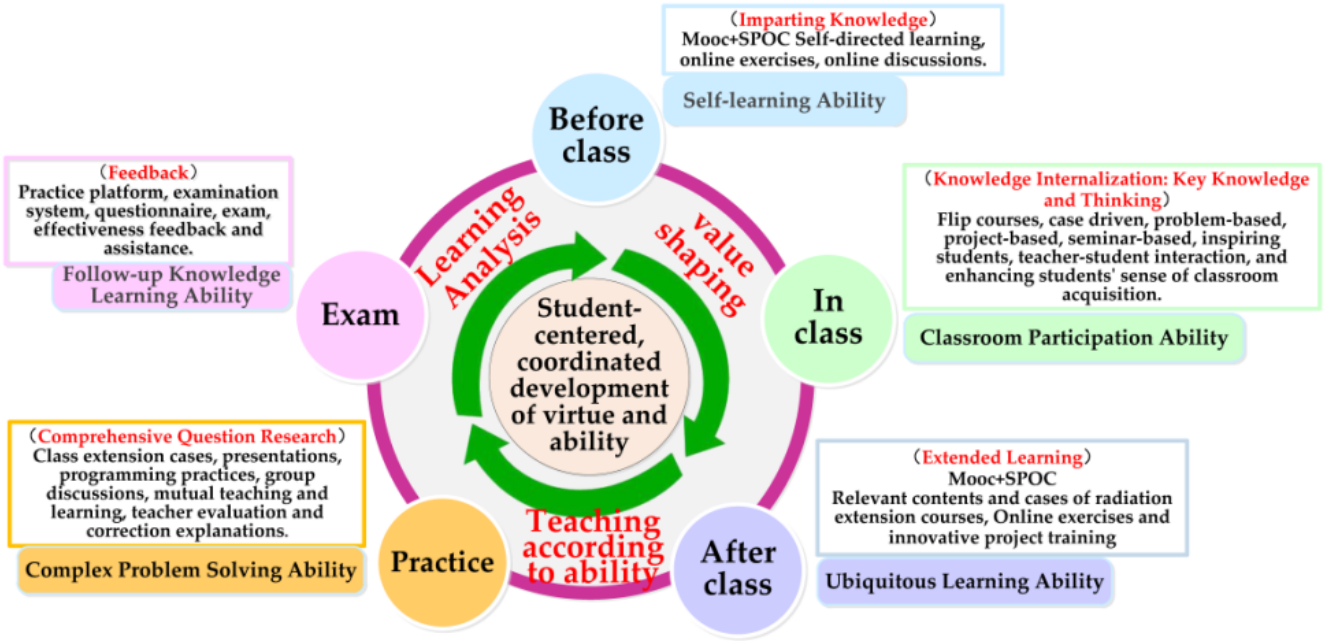


Figure 4. Innovative teaching methods.

(7) Reform course evaluation and realize diversified course performance evaluation conducive to course achievement degree analysis.

OBE is a theory of education that bases every part of the educational system on objectives. As an advanced educational philosophy, the concept of OBE was first introduced by Spady. OBE-based course assessment aims to collect student learning outcomes and to objectively estimate the completion rate of course objectives corresponding to graduation requirements [34]. Under the guidance of OBE to create the education philosophy for engineering education, we need to pay attention to the process control of daily teaching. As course teachers, we need to change our mindset and change past practices of determining whether students' learning is good or bad by one examination paper. We should pay more

attention to diversifying course assessments and take the idea of process control as the guide to assess and evaluate students' learning performance during the whole process.

Therefore, we need to pay particular attention to data collected regarding the student learning process through multiple online and offline channels to support the analysis of the degree of course achievement. In addition, we have developed a "1234" course co-examination mechanism with Hunan Agricultural University and Jishou University to evaluate course summative examinations. The "1" refers to the objective of how to reform and innovate the teaching methods and approaches of C programming courses to enhance students' innovative and practical abilities. Next, "2" refers to the fact that joint examination consists of two parts: a theoretical examination and a practical examination. The next step, "3" refers to the process of joint examinations in three steps: the first step is to discuss the joint examination plan together before the examination and to jointly design the questions; the second step is to conduct examinations simultaneously on the same examination platform; the third step is to summarize and analyze the results shortly after the examination and strengthen communication through seminars. The final step, "4", refers to four guarantees: firstly, each school encourages and supports the joint course examinations; secondly, it establishes a working platform for communication on joint examination affairs; thirdly, it uses the joint examination platform to achieve the same examination paper, the same time, the same platform, and automatic score raising, to realize the joint examination in the true sense; fourthly, all parties regularly hold joint examination course teaching reform experience seminars to exchange experiences in course teaching. The joint examination mechanism of the course reflects the separation of teaching and examination, and the content of the assessment reflects the student's mastery of knowledge and the achievement of their practical ability.

(8) Building the ecology of the curriculum with ideological politics and forming an ecology of moral education that is conducive to implementing the goal of educating people about morality.

Ideological politics in the curriculum is an innovative concept to implement the fundamental task of education: building moral character. Teachers should not only impart professional knowledge but should also start from the essence of "educating people," paying attention to the ideological and political elements in teaching professional courses and focusing on value leadership [35]. By effectively implementing the goal of shaping moral character in teaching, we can guide students to establish a positive and courageous outlook on life and values by exploring the ideological and political education resources contained in the course through multiple channels and angles in an all-round way to build everything silently through an ecology of ideological and moral education.

4.2. Construction of Teaching Model

Based on the systematic reform of the above eight dimensions, we have created an information-based teaching environment that realizes the collaborative integration of online and offline, in-class and after-class, and pre-class and after-class learning and that meets the new teaching ecology of "golden course" construction, engineering education professional certifications, and the ideological and political needs of the curriculum in the new era. It fully embodies student-centered learning, meeting students' individual needs, stimulating learning interest and initiative, and subtly stimulating innovative spirit and critical thinking. On this basis, we have built a teaching model of "three classrooms–four integrations–five combinations" for the C language programming course. A schematic representation of the teaching model is shown in Figure 5.

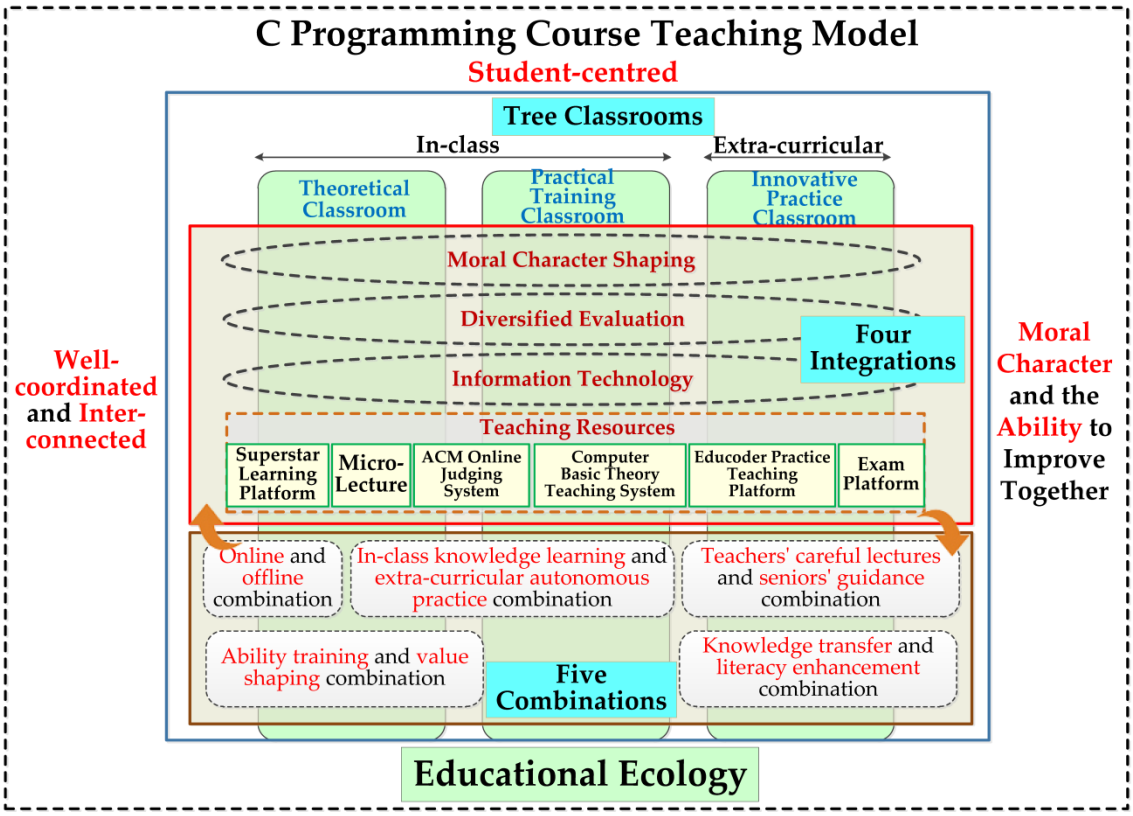


Figure 5. "Three classrooms–four integrations–ive combinations" teaching model.

In Figure 5, the "three classrooms" refers to the division of the teaching classroom into a theoretical classroom, a practical training classroom, and an innovative practice classroom. "Four integrations" refers to organically integrating teaching resources, information technology, diversified evaluation, and moral character shaping into each classroom. "Five combinations" refers to the combination of online and offline in-class knowledge learning and extra-curricular autonomous practice, teachers' lectures and guidance from seniors, ability training and moral character shaping, and imparting knowledge and innovative practice in course teaching. The teaching model fully embodies the synergy created by the eight dimensions of holistic reform. It coordinates well and interconnects the various aspects, resources, and methods of course teaching. The teaching model is always student-centered and effectively achieves the imparting of knowledge, the training of creative and practical ability, and the shaping of moral character.

5. Teaching Reform Features and Innovations

5.1. Teaching Reform Features

(1) This course teaching reform focuses on a holistic approach. With the synergy formed by the eight dimensions of systematic reform, a new ecology of education has been built to meet the needs of "golden course" construction, engineering education professional accreditations, and ideological politics in the curriculum in the new era.

(2) A course co-examination mechanism has been constructed with provincial universities, creating a new model for course examinations. Post-exam analyses and summaries were made promptly, and methods for teaching the course and ways to improve teaching quality were explored collaboratively through seminars, opening up a new way for the course to be built jointly by multiple schools.

(3) The classroom teaching, practice, and independent learning system have been improved. Deepening students' understanding and awareness of course knowledge,

fully mobilizing their enthusiasm and initiative, and cultivating their innovative thinking and practical ability have achieved remarkable results.

5.2. Teaching Reform Innovations

(1) The teaching model of "three classrooms–four integrations–five combinations" has been established. In the classroom, teachers provide lectures on key and difficult knowledge, and the students complete the course pre-study and practice independently before and after class based on the online platform resources. The three-dimensional classes and open teaching resources have achieved better results, enabling students to grasp knowledge, make break throughs in key and difficult knowledge, and realize the synergy of ability training, the ideological politics in the curriculum, and moral character shaping.

(2) The effective four-in-one teaching strategy of "understanding during learning, strengthening during exercises, consolidating during practice, and innovating during breakthrough" is used to implement the teaching model. The course teaching highlights the students' main role and cultivates their innovative spirit, teamwork, and sense of social responsibility.

6. Course Evaluation and Reform Effect

6.1. Evaluation of the Implementation Process

Expert evaluation: Professor Zou, a member of the Steering Committee of Computer Teaching of the Ministry of Education and a member of the National Research Association of Basic Computer Education in Higher Education, and Professor Chen, a member of the Steering Committee of Software Engineering Teaching of the Ministry of Education and an expert in China's engineering education accreditation, evaluated this course highly. They unanimously agreed that the teaching mode of "three classrooms–four integrations–five combinations" and the four-in-one teaching strategy align with the concept of OBE engineering education. It is an excellent offline first-class undergraduate course that fully reflects the high level, innovation, and challenge of the course and effectively achieves the training objectives of the course.

University evaluation: The overall teaching scores of the teaching team of this course were excellent. The university supervisory team considered that the teaching mode of this course was advanced, the classroom teaching interaction was good, and emphasis was placed on the cultivation of students' practical ability, process evaluation, and diagnostic improvement. The curriculum's ideological politics could be naturally integrated into classroom teaching, and the course objectives could be effectively achieved.

Student evaluations: The course is very popular among students, and at the end of each semester, students rate the teaching of the course as excellent. For example, the average score of the most recent evaluation was 95.67, ranking first among all courses in the school. Students think that this course's teaching is lively, interesting, and interactive; has close integration of theory and practice; and the teacher can effectively motivate students to learn and guide them on how to learn, laying a solid foundation for future course learning. The course is rich in teaching resources and learning platforms, which is helpful for independent learning. At the same time, the teacher can guide students to develop healthy values in the classroom effectively.

Graduate comments: Looking back on the courses we took at university after graduation, we believe that the C Programming course left a deep impression on us. The course has an innovative teaching model, the teachers are conscientious and responsible, the teaching is lively, creative thinking is properly guided, and the teaching methods and strategies are suitable for beginners. The course content is innovative and challenging, and the course practice can effectively enhance the creation of solutions to complex engineering problems, which has laid a solid foundation for our work and is a very good course.

6.2. Evaluation of the Effectiveness of the Course Teaching Reform

6.2.1. Significant Improvement in Students' Exam Results

Examinations are an important means of testing teaching effectiveness and evaluating students' learning. They occupy an important place in school management and evaluations of teaching quality, so the quality of examination papers used for examinations is the basis and prerequisite. The analysis of examination papers includes the analysis of examination results and the analysis of the quality of examination papers, which are also necessarily linked. Therefore, analyzing examination papers is a particularly important aspect of teaching.

The joint examinations for the C Programming course started in 2013. The schools taking part are the School of Computer and Artificial Intelligence at Huaihua College (HHU), the College of Information and Intelligence at Hunan Agricultural University (HUNAU), and the School of Communication and Electronic Engineering at Jishou University (JSU). Hunan Agricultural University and Jishou University are first-class institutions in Hunan Province, and students are admitted with higher scores than at Huaihua University. After the first joint course examination, based on the known theoretical and practical examination results and the number of participants, the difficulty, discrimination, and grade reliability [36] of the exam were analyzed according to Ebel surveying and Cronbach's coefficient estimation methods. The results shown in Figure 6 were obtained.

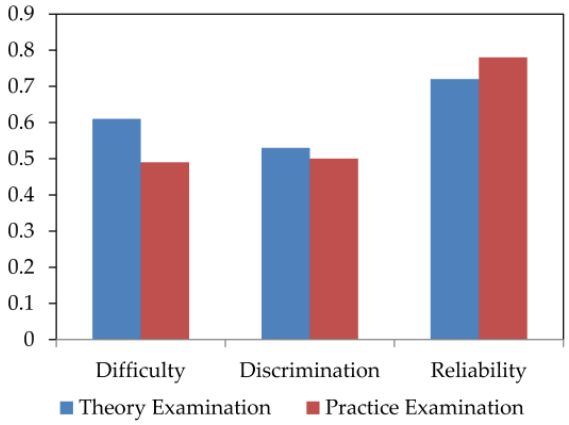


Figure 6. Results of the quality analysis of the first three-school joint examination papers from 2013. Note: Generally, exam papers with difficulty values greater than or equal to 0.7 are identified as easy, those greater than 0.4 and less than 0.7 are designated as a medium, and those less than or equal to 0.4 are identified as difficult. A discrimination scale of 0.4 or above indicates the best discrimination, 0.3–0.39 indicates good discrimination, 0.2–0.29 indicates not very good discrimination and revision requirements, and 0.19 or below indicates poor discrimination and should be eliminated. The exam paper's reliability should normally be greater than 0.7 [36].

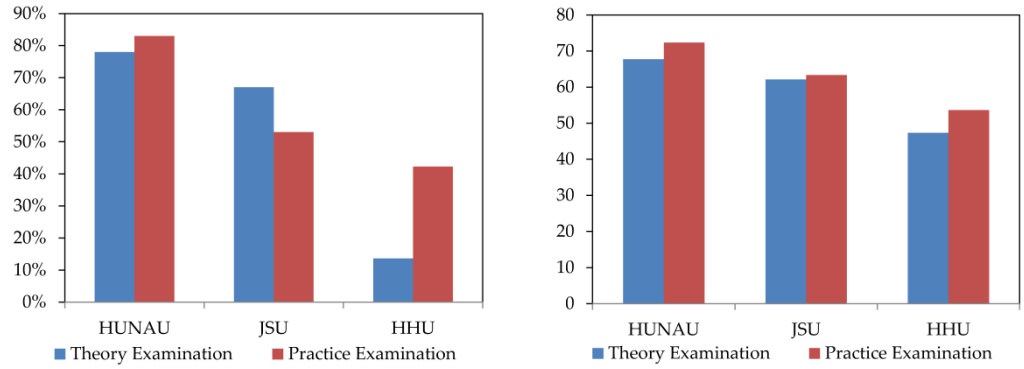
As can be seen from Figure 6, the difficulty values for the theory and practical examinations for that year were in the (0.4, 0.6) range, indicating ideal difficulty control. The discrimination was greater than 0.4, indicating that the ability to differentiate the examination met the requirements. The reliability coefficients were greater than 0.7, indicating high confidence in the examination results. The quality of the examination papers is good.

A comparison of the examination results for each of the three schools for that year is shown in Figure 7.

It is clear from Figure 7 that the average scores and the pass rates of both theoretical and practical examinations at Huaihua University during that year were much lower than those of Hunan Agricultural University and Jishou University.

After that examination, we found serious flaws in the teaching of the course. At the first seminar, we listened carefully to the practices of the two schools. After that, we started to work on the course teaching reform, combining the characteristics of our students. Over

nine years, we have gradually developed our teaching model and teaching strategy through continuous improvement. In the subsequent years of the three-school joint examination process, we ensured that the theory and practical e difficulty, differentiation, and reliability of the examinations were reasonable (as shown in Table 1). We achieved average scores and pass rates that were constantly close to or even higher than those of the other two schools. The results are shown in Figures 8 and 9.

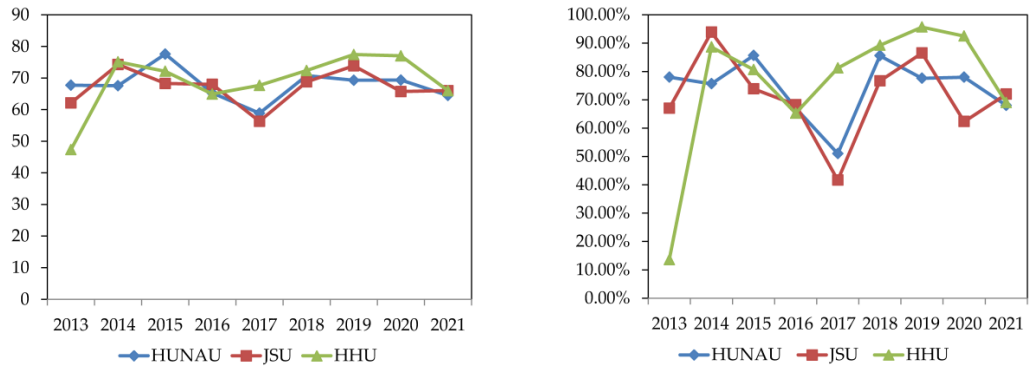


(**a**) (**b**)

Figure 7. A comparison of pass rates and average scores for the three-school joint examination. (**a**) shows the pass rates comparison, and (**b**) shows the comparison of the average scores.

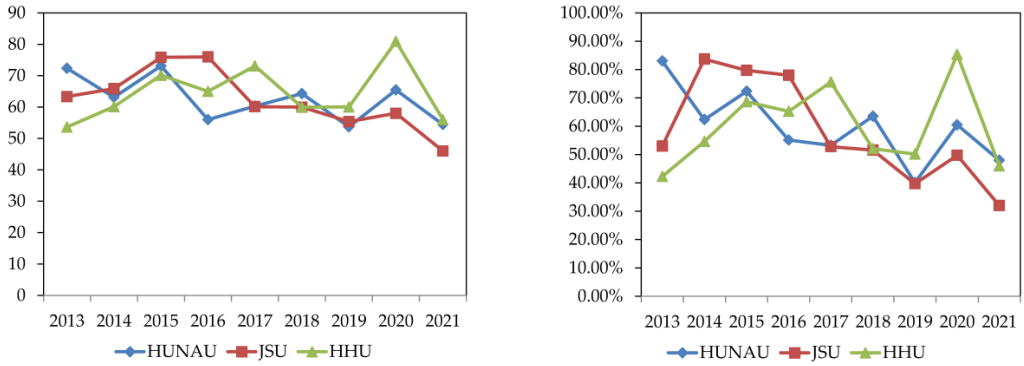
Table 1. Analysis of examination papers over the years.

Year	Number of Exam Participants	Difficulty		Discrimination		Reliability	
		Theory	Practice	Theory	Practice	Theory	Practice
2013	816	0.612	0.491	0.532	0.501	0.721	0.782
2014	827	0.751	0.602	0.473	0.401	0.824	0.667
2015	862	0.666	0.639	0.425	0.615	0.685	0.701
2016	968	0.667	0.738	0.441	0.427	0.702	0.718
2017	963	0.608	0.660	0.491	0.417	0.715	0.705
2018	1075	0.706	0.617	0.441	0.614	0.792	0.727
2019	1158	0.729	0.559	0.468	0.526	0.856	0.801
2020	1217	0.702	0.678	0.526	0.623	0.849	0.823
2021	1452	0.472	0.537	0.643	0.702	0.784	0.814



(**a**) (**b**)

Figure 8. Comparison of average scores and pass rates for the theory exams of the three schools from 2013 to 2021. (**a**) shows a comparison of average scores in the theory exam, and (**b**) shows a comparison of pass rates in the theory exam.



(**a**) (**b**)

Figure 9. Comparison of average scores and pass rates for the practical exams of the three schools from 2013–2021. (**a**) shows a comparison of average scores in the practical exam, and (**b**) shows a comparison of pass rates in the practical exam.

It is clear from Table 1, Figures 8 and 9 that the quality of the examination papers produced by the joint examination proposition group in the annual three-school joint examinations is in line with the examination requirements. The difficulty and discrimination are kept within a reasonable range, and the results are credible. We have made continuous reforms to the teaching of the course, and the results are significant. The effective improvement of the course scores in the three-school joint examinations has demonstrated the viability of our proposed overall teaching reform program. The teaching model and strategy developed in the reform meet the needs of teaching C programming in our local universities.

6.2.2. High Achievement of the Engineering Education Professional Certification Graduation Requirements Supported by the Course

Since China's engineering education program joined the Washington Accord in 2016, our school comprehensively revised the talent cultivation plans for all majors in 2018 to produce students who meet the requirements for professional accreditations in engineering education. As a key engineering foundation course, the C programming course needs to effectively support the three graduation requirements of engineering knowledge, research, and communication. We have revised the syllabus to establish the weighting of the three-course objectives and their correspondence to effectively support the three graduation requirements and to standardize the steps and data used to calculate course achievement degrees. For example, we determined the weighting of the three-course objectives to support course achievement as 0.4, 0.4, and 0.2, respectively, and the assessment of each course objective consists of classroom performance (0.1), homework and practical grades (0.3), and examination grades (0.6). Classroom performance consists of class exercises (0.3), topic discussions (0.4), and independent study before class (0.3), while homework and practical scores consist of usual homework (0.3), in-class practicals (0.4), and out-of-class practicals (0.3). The equation for calculating course achievement degree is shown in Equation (1).

$$CObj = \sum_{i=1}^{3} \left(\sum_{j=1}^{\max_i} \left(\frac{aver_j}{item_j} \times w_{i,j} \right) \times w_i \right) \quad (1)$$

where $CObj$ is the course achievement degree, $\max_i$ denotes the total number of assessment items used to calculate the i_th course objective, $aver_j$ is the average score of item j under the course objective, and $item_j$ is the target score of item j under the course objective. w_i is the weight of the i_th course objective, and $w_{i,j}$ is the weight of item j under the i_th objective.

The reform we have undertaken for teaching the C programming course meets the requirements for the engineering education professional accreditation course exactly. The various types of valid data from the teaching process strongly support the course's achieve-

ment degree. The higher degree of course achievement since 2018 has effectively supported the graduation requirements of the relevant majors of the school and has been well received by the school. The details are shown in Table 2.

Table 2. Evaluation of the achievement degree of course objectives.

Year	2018			2019			2020			2021		
Course objective achievement degree	Obj1	Obj2	Obj3	Obj1	Obj2	Obj3	Obj1	Obj2	Obj3	Obj1	Obj2	Obj3
	0.791	0.625	0.809	0.784	0.620	0.714	0.756	0.803	0.768	0.757	0.645	0.781
Weights	0.4	0.4	0.2	0.4	0.4	0.2	0.4	0.4	0.2	0.4	0.4	0.2
Course achievement degree		0.728			0.705			0.777			0.717	

Obj1, Obj2, and Obj3 represent C programming course objective 1, course objective 2, and course objective 3, respectively.

6.3. Achievements and Application of the Course

6.3.1. The Teachers' Ability to Build and Reform the Course Has Improved Significantly

After nine years of continuous teaching accumulation and innovative reforms, the teaching team has been awarded five provincial teaching reform projects related to this course. The course was recognized as a provincial first-class undergraduate course in 2019. In addition, two teachers have been recognized as provincial young backbone teacher-training objects, five teachers have been recognized as double-qualified teachers, and six have been recognized as excellent subject competition instructors. Teachers have also won the first and second prizes in the Information Technology Teaching Competition and the Curriculum Ideological Politics Teaching Competition. Three teaching materials have been published.

6.3.2. Students' Sense of Acquisition Is Increased, and Their Practical Ability, Innovation, and Moral Character Are Improved

"Student-centered" means that teachers pay more attention to students' learning in the teaching process and adopt teaching methods and strategies aimed at helping students to construct their own understanding of the content they are learning. The teaching model we have developed and the teaching strategies we have adopted for the C programming course fully reflect the connotation of "student-centeredness". It has emphasized student-centeredness, enhanced students' ability to learn independently, and focused on developing students' practical and creative abilities and shaping their moral character and achieved good results.

There has been a profound transformation in the way students learn. Students' motivation, initiative, and satisfaction with learning have continued to rise, and their sense of acquisition has increased. Students' critical thinking, cooperation, communication and self-management, self-learning, and self-service literacy have been significantly enhanced, and students' programming practices have been significantly improved. In the past nine years, team teachers have guided students to win 318 awards in various programming competitions, as shown in Table 3. Students have been guided to apply for 19 national and 50 provincial innovation projects, apply for 115 software copyrights and 15 patents, publish 39 papers and participate in developing more than 30 local service projects.

As the fundamental task of school education, ideological politics in the curriculum moves school education from "educating scores" to "educating people". In 2014, the Ministry of Education's Opinions on Deepening Curriculum Reform and Implementing the Fundamental Task of Fostering Virtue through Education proposed cultivating "people with all-around development". In 2016, the Ministry of Education's Core Quality for Student Development in China explained the connotation of a "fully developed person", which includes three dimensions: cultural foundation, independent development, and social participation. These three dimensions are subdivided into six core qualities: humanistic connotations, scientific spirit, learning to learn, healthy living, responsibility, and practical

innovation. Therefore, assessing students' moral development is inevitably based on these six core qualities. Moral behavior [37] is the final link in the formation of moral character, which refers to the activities of moral significance for others and the society that individuals show under the control of certain moral consciousness. Therefore, moral behavior can be used to measure the development of students' moral character.

Table 3. Statistics of course team teachers guiding students to win various programming competitions, 2013–2021.

Award Level	Competition Name	First Prize	Second Prize	Third Prize
National level	China University Computer Competition National Finals—Group Programming Ladder Tournament	2	1	3
	Lan Qiao Cup Individual Competition (Software Category) National Final		14	15
	China Collegiate Programming Contest—National Invitational Contest		2	1
	ACM-ICPC Asia Regional Programming Contest		1	6
Provincial level	China University Computer Competition Provincial Competition—Group Programming Ladder Tournament	1	4	7
	Lan Qiao Cup Individual Competition (Software Category) Hunan Regional Competition	38	76	92
	Hunan Collegiate Programming Contest		12	26
	CCF Collegiate Computer System & Programming Contest		1	4
	China Collegiate Computing Contest—WeChat Small Program Application Development Competition		1	1
	"Oracle Cup" National Java Programming Contest Middle South Division		8	2

In the past nine years, we have subtly cultivated noble moral sentiment, good moral behavior, and a hard-working learning spirit among students by integrating ideological politics into the curriculum and course teaching. Students' ideological and moral qualities have been effectively improved, students' consciousness and initiative have been continuously improved, the enthusiasm for participating in public welfare activities has been rising, the enthusiasm for participating in social practice activities has surged upward, and the awareness of laws and regulations has been continuously enhanced. Students set up the correct ideals, beliefs, and values; demonstrate outstanding performance; are positive, law-abiding, honest, and trustworthy; are willing to dedicate themselves to a cause; have good moral behavior. Many moral models of law-abiding citizens with noble morality, strong will, and outstanding knowledge have emerged among students. Their excellent quality of high moral character, strong-willed, diligent thinking, self-improvement and scavenging have been highly praised by all sectors of society.

For example, we have cultivated 45 moral and ethical models of moral characters, such as Feng Xiaoxu, Gao Xing, Zhu Jiahe, Feng tian, Wang Songxiang, Wu Yao, Xie Qie, Li Jie, Chen Kemeng, etc., who have been recognized as "Star of Self-Improvement", and Ding Li, Dai Shen, etc., who have been recognized as "Moral Pioneer". There have been many outstanding deeds among students, such as Wang Liang, who found money and did not take it for himself. Dong Shouming volunteered to donate platelets to veterans. Ding Hao, Qin Jian, and Duan Ke volunteered to serve on the front lines of epidemic prevention and control in their hometown. Liu Xiaokang and Li Jiawei donated many epidemic prevention materials in gratitude to the school and teachers.

All of the students have volunteered in many public welfare activities, such as "giving love to the community", "volunteering to repair computers", and "visiting the elderly in homes for the elderly". The volunteer team has been awarded as the "Excellent Service Team", and many students have been awarded as "Excellent Volunteers" and "Excellent Practice Team Members". Yin Xiaoyi was awarded the titles of "Pioneer of Student Double

Creation" and "Advanced Individual in Practicing Socialist Core Values" by the Central Committee of the Communist Youth League.

According to data from a recent survey conducted by MICOS, a third-party survey agency, employers are 99% satisfied with our graduates. It has been evaluated that the students we cultivate have a strong sense of social responsibility, strong technical ability, and excellent moral character.

6.3.3. The Experience of Replicable and Sustainable Course Teaching Reform Has Generated a Strong Response

The innovative teaching model has been applied to 12 other courses, such as "Java Programming", "HTML5 Application Development", "Data Structures", "Software Engineering", etc. Table 4 lists the time when these courses started to apply this teaching model, the years they have sustained its form, and the honors they have received and including six first-class undergraduate courses in Hunan Province and four first-class courses at Huaihua University. This shows that the teaching innovation model is significant for teaching local-type engineering courses.

Table 4. Main courses applying the teaching model.

No.	Course Name	Start Time	Lasting Years	Course Honor
1	Java Programming	2015	8	Hunan first-class course
2	HTML5 Application	2017	6	Hunan first-class course
3	Software Engineering	2017	6	Hunan first-class course
4	Computer networks	2018	5	Hunan first-class course
5	University Computer Fundamentals	2018	5	Hunan first-class course
6	Electronic Commerce	2018	5	Hunan first-class course
7	Data Structure	2016	7	School-level first-class course
8	Communication Electronic Circuit	2017	6	School-level first-class course
9	Fundamentals of Circuit Analysis	2018	5	School-level first-class course
10	Principles of Communication	2018	5	School-level first-class course
11	java web Application Development	2019	4	
12	Enterprise Application Development	2019	4	

In Table 4, Start Time indicates the year when the course started using our proposed teaching model, Lasting Years indicates how long the course has been using the model so far, and Course Honor indicates the accolades achieved by the course after applying the model, such as Hunan or school-level first-class courses.

The members of our teaching team shared their experiences in course reform at the annual computer education conference and academic exchange meeting in Hunan Province, generating a strong response and attracting more than ten universities inside and outside the province to learn from us. The relevant education and teaching reform practice results have been reported in more than 20 articles on platforms such as Xinhua Net, Hunan Daily, Huaihua Daily, Huaihua News, and Campus Net, with over 10 million hits on the electronic versions.

7. Conclusions

In this paper, we study the teaching reform of C programming courses driven by the requirements of teaching informatization, the OBE concept in engineering education, "Golden Course" construction, and ideological politics in curriculum. Based on the perspective of sustainable development, we have reconstructed a support system for the teaching reform of C programming courses, created a new ecology of course teaching, and constructed the teaching mode of "three classrooms–four integrations–five combinations" and the "four-in-one" teaching strategy through a holistic and collaborative reform in eight dimensions. In the nine years since the implementation of the teaching reform, the course teaching has achieved good application results.

(1) The teaching model created by the teaching reform has led to a change in the teaching philosophy of teachers from "teacher-centered" to "student-centered", which has facilitated the improvement of the teaching methods and the course strategies. The achievement degree of the course effectively supports the graduation requirements for engineering education accreditations. Since 2013, the course reform has successfully made the C Programming course a high-quality course at Huaihua university and a first-class undergraduate course in Hunan Province.
(2) The teaching mode has helped students to enhance their independent learning ability and to cultivate their practical ability and the ability to solve complex engineering problems. It has deepened students' understanding of the course knowledge and has mobilized their motivation and initiative.
(3) This teaching model has cultivated innovative thinking and has enhanced students' creative abilities, helping our students to achieve fruitful results in winning programming competitions, publishing academic papers, applying for student innovation projects, applying for software copyrights, applying for patents, and participating in local project development services.
(4) The teaching mode focuses on fostering virtue through education, which is conducive to cultivating students to have a correct outlook on life and values and cultivating a group of students with good character and a strong sense of social responsibility.
(5) The teaching mode has achieved a good promotion effect. It has been promoted and applied to 12 engineering courses in our university, with six courses being recognized as first-class undergraduate courses at the provincial level, and four being recognized at the university level.

These results show that the pedagogical reform and the teaching model that we built for the C programming course can effectively and synergistically promote knowledge imparting, ability training, and moral character shaping. It can provide a reference for building a student-centered information-based education ecology, creating a high-quality classroom, and collaboratively enhancing students' abilities and moral character in university engineering courses. Other types of courses are less suited to this mode of teaching.

The data and information on the outcomes of this study are all publicly available and do not raise privacy or ethical issues. In this study, we have used these data and information in a scientific and standardized manner to demonstrate that the course teaching reforms have a positive impact on educational development and can be sustainable and that there is no research misconduct or the narrative of structural crisis [38].

The teaching reform and teaching mode of the course are still continuously improving as big data and artificial intelligence technologies are becoming more widely used in education and teaching [39,40]. It would be meaningful for new research to study how to integrate big data technology in the teaching model to uncover the learning behaviors hidden in the learning process data [41], to form student ability portraits [42] to intelligently guide students to adjust their learning behaviors [43] and to provide intelligent recommendations for teachers to teach accurately [44].

Author Contributions: Conceptualization, D.Y. and X.Z.; formal analysis, D.Y. and Y.L.; investigation, Y.L.; data curation, X.Z.; writing—original draft preparation, D.Y.; writing—review and editing, X.Z; visualization, D.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Research Project on Teaching Reform in Hunan Province General Higher Education Institutions under grant number HNJG-2022-0277 and the First-class Course of Hunan Province ([2020]9).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors are very grateful to the reviewers for their pertinent comments, which have enabled us to improve the quality of this article.

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

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